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The competitiveness and evolving geography of British manufacturing: where is manufacturing tied locally and how might this change?

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The competitiveness and evolving geography of British manufacturing: where is manufacturing tied locally and how might this change?

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Executive summary

The report explores the competitiveness and evolving geography of British manufacturing with a focus on identifying key trends and developments that have the potential to produce a new geography of manufacturing. The key questions are: where is manufacturing tied locally, how might this change, and what are the drivers behind these changes? The report's conclusion is that manufacturing is at the start of a new industrial revolution that will transform the geography of British manufacturing. This revolution is driven by the emergence of new manufacturing technologies and alterations in the inputs required to manufacture products.

The new industrial revolution in the geography of global manufacturing is in its very early stages. It will vary dramatically from industry to industry, depending on technology, transportation costs, labour content, the competitive strengths of countries with low labour costs and the strategies of individual firms. The drivers of this new geography of manufacturing are complex and include alterations in factor inputs, transformations in manufacturing technologies and the blending of services with manufacturing to create new hybrid production systems and hybrid products.

The on-shoring or return of manufacturing to the UK from lower cost locations is partly driven by increasing transportation costs, but also a concern with quality and producing goods closer to the market. Balancing cost control with non-cost elements of product – heritage, design, location, speed of delivery, customisation – is becoming an important element of manufacturing competitiveness. For many British manufacturing companies labour costs have become a relatively minor element of overall costs. Increasingly energy costs are becoming a more important influence on the geography of manufacturing. Energy costs take two forms. First, there is the energy required to produce a product and, second, the energy involved in transportation. Escalating energy costs have important implications for manufacturing policy in the UK as energy costs and availability could drive manufacturing offshore.

A process of hybridisation between manufacturing and services is occurring, leading to the production of hybrid products or products containing a complex combination of services and manufactured inputs. All production systems are hybrid systems that are based on a blend of service and manufacturing activities, but not all hybrid production systems produce hybrid products. The blurring of the division between manufacturing and services and the rise of hybrid production systems and hybrid services represents an important opportunity for British manufacturing. The importance of hybrid production systems and the emergence of hybrid products suggest that the UK no longer requires an industrial policy, but a production policy. An industrial policy represents a policy solution for the last century rather than the current century. The rise of hybrid production highlights the importance of the relationship between manufacturing and services. It also implies that manufacturing firms will increasingly invest in service facilities that will be required to support hybrid products. These new service facilities will have a different geography to manufacturing plants as some will be required to be located close to market and most will require access to skilled labour. This implies that the geography of manufacturing is also changing as it includes the provision of manufacturing facilities and service facilities.

A critical driver behind the new manufacturing revolution is technological developments. New production processes and technologies will transform manufacturing. Developments in additive and digital manufacturing are both an opportunity and threat to British manufacturing. An opportunity as manufacturing firms based in the UK will be able to produce customised products that would be impossible to create with conventional machine tooling. A threat as the UK is yet to develop significant capability in the production of 3D printers and in the supply of 3D printing powder.

Manufacturing is a diverse sector of the UK's economy. It includes activities ranging from aerospace and steel production to textile manufacture and the production of food and drink. In 2010 manufacturing accounted for 11.8% of employment in the UK, 14.1% of enterprises, 18.2% of turnover and 19.4% of gross value added (GVA). Over the period 2008-10 employment in manufacturing declined by 8.1%, the number of manufacturing firms declined by 11.1% but turnover grew by 2.5% and GVA by 0.9%. Areas of growth by value included pharmaceuticals, aerospace and the production of coke, petroleum and nuclear fuel while areas of decline by employment included textiles, basic metals and processes, rubber and plastic products and automotive.

Over the last 40 years, UK manufacturing has experienced reductions in employment combined with continual restructuring. These two processes have led to the formation of new forms of manufacturing and alterations in the spatial distribution of manufacturing. Manufacturing's contribution to employment is declining as services have grown at a much faster rate. Manufacturing output has continued to grow, but at a much slower rate compared to services. This reflects a relative rather than absolute decline in manufacturing. The decline of manufacturing in the UK is based on a decline in employment rather than output. This represents 'jobless growth' based on improvements in productivity; manufacturing has been transformed through investments in new technology combined with process improvements.

Since the 1980s, two interrelated processes have been central to thinking about the emerging character and geography of manufacturing. On the one hand, the on-going formation of a global economy and the development of complex global production systems have played a central role in debates. On the other hand, there has been a focus on regions and on understanding the drivers of local economic development and especially local agglomerations or processes of clustering. Regions compete with one another on the basis of their regional assets. Some productive inputs (land, tools and equipment, labour and skills, etc.) are regionally differentiated. Place-specific economic and non-economic (history, brands, etc.) factors play an important role in the competitive advantage of regional economies.

Existing approaches to understanding regional economies have emphasised the importance of the 'three R's' - the relocation of production, the restructuring of work and the redistribution of costs and work. This approach highlights price-based competitiveness based on cost control; cost control is critical for the competitiveness of manufacturing companies. Nevertheless, companies compete on more than just price, but also a set of factors that are not directly related to price (design, location, brand, history, technology, etc). These factors represent a unique set of advantages providing a firm with monopolistic competition.

The experience of UK manufacturing over the period 2008 to 2010 highlights continued productivity improvements. Automotive (Standard Industrial Classification (SIC) code 29) exports increased by 13.8%, but employment declined by -21.8%. Similarly the export of leather products (SIC 15) increased by 45.8% whilst employment declined by -19.0%. In only two areas of manufacturing was export growth associated with employment growth.

'Other transport' (SIC 30) experienced an increase in employment growth of 46.1% and in exports of 43.9% while 'exports of wearing apparel' (SIC 14) increased by 34.1% and employment by 9.9%.

A detailed analysis of nine manufacturing sub-industries that are important for strengthening the UK's export base and are also sectors involving high-value added manufacturing is undertaken in the report. The industries are: 1) Food Products (SIC 10), 2) Fabricated Metals (SIC 25), 3) Other Machinery and Equipment (SIC 28), 4) Automotive (SIC 29), 5) Computers, Electronic and Optical Equipment (SIC 26), 6) Chemicals and Chemical Products (SIC 20), 7) Aerospace (SIC 30.3, 33.16), 8) Pharmaceuticals (SIC 21), 9) Wearing Apparel (SIC 14).

More traditional industries have geographies that are closely related to localised concentrations. Such industries include basic metals (SIC 24), shipbuilding (SIC 30.1), tobacco products (SIC 12), computer facilities (SIC 15), computer facilities management (SIC 62.03), coke products (SIC 19), aerospace (SIC 30.3), leather products (SIC 15) and wearing apparel (SIC 14). All exhibit extreme localisation.

The more footloose industries are computer, electronic and optical equipment (SIC 26), electrical equipment (SIC 27), other machinery and equipment (SIC 28), other manufacture (SIC 31.32), specialised design (SIC 74.1), food products (SIC 10) and wood products (SIC 16). These more footloose sectors tend to be much more heterogeneous and/or have developed more recently.

Traditionally, older manufacturing regions have often been considered to be locked into outmoded technologies while innovative production develops in new regions. This represents path dependency in which previous decisions and investments determine current investments and economic outcomes. This view has been challenged by research that shows that firms in older industrial regions have the potential to evolve and to break out from path dependency to create new development pathways.

Phoenix industries based in older manufacturing regions have emerged as firms benefit from pre-existing personal networks, technical skills, and market knowledge that have developed over a long time. Older manufacturing regions possess strategic assets including specialised engineering departments and research programmes that provide firms with opportunities to reinvest themselves.

Since 2008, a new trend has emerged in the geography of production. This is 'onshoring' or 'reshoring' or the repatriation of production work back to the UK. Manufacturing firms used to be primarily concerned with differences in labour costs, but increasingly firms are developing a holistic account of total costs and related risks. This means that the location of a manufacturing facility may be determined by other factors apart from labour costs. Three processes can be identified. First, there is the repatriation of production to the UK from low-cost locations. Second, investment in on-shore production capability that enhances capacity is occurring and, third, companies that were sourcing components from overseas are switching to local producers. The reasons why manufacturing is coming back to the UK are the same reasons why - for many successful manufacturers - it never strayed abroad.

Two on-going developments have important implications for the future of UK manufacturing: 1) China's demographic time bomb and 2) new technologies. First, China has about 108 million elderly (people aged 65 and over), or over one-fifth of the world's elderly population, and this number is expected to triple by 2050. China will become an ‘old’ society before its economic development is ready to underwrite the fundamental economic and political challenges posed by such demographic transition. This means that China will face labour and skill shortages and will find it increasingly difficult to compete on the basis of low-paid labour.

Second, the history of much manufacturing is based around ‘subtractive’ methods in which material is removed by cutting or drilling. Subtractive manufacturing has been supplemented by technological developments that have given rise to ‘additive’ manufacturing techniques, rapid prototyping or 3D printing. 3D printing makes it possible to produce light weight structures that are extremely strong optimising the relationship between material content and performance. Additive manufacturing will produce entirely new businesses, new business models and a new geography of manufacturing. Additive manufacturing is one of the most important technological or digital developments in manufacturing since the introduction of Computer Aided Design (CAD). It is critical that the UK is at the forefront of the development and application of 3D printing and other digital technologies to manufacturing.

The availability of individuals with suitable skills plays an important role in the continuing competitiveness of UK manufacturing. The emphasis that has been placed by educational establishments on quality graduate employment has led to skill shortages in manufacturing as service businesses have attracted talented individuals. Such shortages include very skilled labour as well as semi-skilled employees. Many manufacturing firms are experiencing great difficulty in recruiting skilled employees and this is holding back economic growth. Developing sustainable solutions to the skills problem is critical for the long-term competitiveness of UK manufacturing. The existing location of manufacturing firms has evolved through various forms of path dependency or geographical inertia. The existence of concentrations of manufacturing activities led to the emergence of a supporting infrastructure of educational institutions. The link between the research and innovation ecosystem in a locality is complex as the best companies identify the best research organisations to work with irrespective of location; smaller firms either draw upon their own responses or use local providers. The education of skilled workers is complex as it requires skills that are developed in universities and further education establishments as well as employer provided training. Economic growth within UK manufacturing requires an approach that will carefully align educational provision with the needs of major industrial sectors. This is a complex task that requires careful coordination of national and local policies.

This report highlights the current state of UK manufacturing. The analysis points to real potential for sustained growth in established sectors where design and innovation play a key role in production processes and not just in end products. Manufacturing policies must be designed and implemented that are based on an understanding of the spatial organisation of production, an appreciation of the on-going hybridisation that is occurring between goods and services, the importance of non-price based competitiveness, the emergence of additive manufacturing and new digital technologies and the problems related to skill shortages and hard-to-fill vacancies.

1. Introduction

The report explores the competitiveness and evolving geography of British manufacturing with a focus on identifying key trends and developments that have the potential to produce a new geography of manufacturing. The key questions are: where is manufacturing tied locally, how might this change, and what are the drivers behind these changes?

The analysis draws upon recent theoretically informed empirical research that challenges existing approaches to understanding the changing location of manufacturing industry. Central to this analysis is a concern with understanding the internal drivers of change within the UK and also external drivers that are altering the location of manufacturing activity. From the 1970s the dominant account of manufacturing, academically and politically, has revolved around debates that highlighted the on-going deindustrialisation of manufacturing in the UK in response to the emergence of global competition (Blackaby, 1978; Lever, 1991). Accounts of deindustrialisation emphasised the collapse in manufacturing employment rather than continuity of manufacturing production and also on-going growth in the output of the manufacturing sector. This deindustrialisation literature needs to be replaced by a more sophisticated analysis of manufacturing that highlights new technologies, processes and materials combined with alterations in the inputs required to produce high-value added manufacturing products (Bryson and Rusten, 2011).

There are five basic questions that must be asked about manufacturing: why does it take place, what is produced, how is production organised, where is production located, and how do the why, how, what, and where change over time? These are critical questions for anyone interested in understanding the continued evolution of manufacturing in the UK. It is important to accept that the answer to these questions revolves around understanding processes of continuity and change. The future of British manufacturing lies in the relationship between these two processes. Central to this relationship of continuity and change are technological developments that have the potential to revolutionise production. Continuity is provided by investments that have been made in the past and the existence of specialised clusters or agglomerations. It is important not to become too preoccupied with economic activities that are intensely localised at the expense of ignoring other ways in which the geography of production is organised. Thus, two types of cluster exist. First, are economic activities that are co-located and have developed some form of functional clustering and, second, economic activities that are not co-located but have still developed functional linkages with firms or economic actor located elsewhere. The latter reflects a form of distributed clustering that will be facilitated by information communication technologies (ICT) and modern transportation. Both types of clustering are important features of the geography of British manufacturing.

The argument in this report is developed over ten sections:

- The analysis is based on a review of existing academic studies informed by the authors' on-going and detailed research into manufacturing in Europe and the US.
- The second section explores the evolution of manufacturing in the UK and provides the context for the analysis.
- The third section explores the on-going blurring of the boundaries between manufacturing and services and the development of hybrid forms of manufacturing.

This challenges the assumption that manufacturing should be considered as separate from the provision of services. This section reviews on-going debates regarding the restructuring of manufacturing and different sources of competitiveness.
- In the fourth section an analysis of processes of relocation, restructuring and redistribution is undertaken. It also explores recent contributions made by evolutionary economics. This part of the analysis explores the ways in which new routines are developed by firms and then spread around regional economies via spinoffs and processes that lead to the development of a functional cluster or agglomeration.
- The fifth section explores the role of place-based inputs in the competitiveness of manufacturing firms.
- In section six the evolving geography of British manufacturing is analysed focussing on nine key sectors. This section is based on an analysis of the *British Register and Employment Survey* (BRES). The focus is on identifying sectors that a play a critical role in the competitiveness of the British economy.
- The seventh section explores different ways of conceptualising manufacturing and older manufacturing regions with a focus on the rise of phoenix industries – old manufacturing activities that have been transformed in to new industries. This analysis covers the period 2008 and 2010. It is possible to argue that this time period is exceptional given the economic downturn, but the focus of the analysis is to identify patterns and geographies that will have been established through investments that have occurred over decades.
- In the eighth section the return of manufacturing to the UK is considered. The focus is on identifying seven drivers that are behind the recent on-shoring of manufacturing to countries like the UK and the US.
- In the ninth section it is argued that the UK is at the start of the ‘next or third industrial revolution’. This new revolution is partly a response to structural problems within China and the role of new digital technologies that have the potential to transform manufacturing. The focus is on an analysis of rapid prototyping or additive manufacturing.
- The final section considers policy responses related to the changing nature of manufacturing.

2. The competitiveness and evolving geography of British manufacturing

Manufacturing is a very diverse sector of the economy of the United Kingdom. It includes activities ranging from aerospace and steel production to textile manufacture and the production of food and drink. In 2010 manufacturing accounted for 11.8% of employment (BRES, 2010a & b), 14.1% of enterprises and accounted for 18.2% of turnover and 19.4% of gross value added (GVA) (ABS, 2010). Over the period 2008-10 employment in manufacturing declined by 8.1%, the number of manufacturing firms declined by 11.1% but turnover grew by 2.5% and GVA by 0.9% (Tables 1 and 2).

Areas of growth by value included pharmaceuticals, aerospace and the production of coke, petroleum and nuclear fuel while areas of decline by employment included textiles (leather), basic metals and processes, rubber and plastic products and automotive. The automotive industry is a significant contributor to GVA (5.5% or the 5th largest contribution) (ABS, 2010) and export levels (16.1%, 2nd largest contributor) (TOPSI, 2012), but has experienced an above average decline in employment between 2008 and 2010 (-21.8% compared to an average decline for manufacturing of -8.1%) (BRES, 2010a & b). Nevertheless, automotive, basic metals and processes and rubber and plastic products are within the UK's top ten exporting industries by value (Table 3).

Key areas for employment growth have been in specialised design, technical testing and research and development (R&D) for engineering and natural sciences. It is often assumed that high-value advanced manufacturing activities are best able to compete from a high-cost location. This is not the case; low-cost locations are trying to move up the value chain to produce high-value products. On the one hand, there are low-value manufactured products that must be manufactured close to market as they are difficult or expensive to transport. Such products include those that are bulky and difficult to transport for example the manufacture of hygienic tissue. On the other hand, there are many low-value products that can be profitably produced in the UK through the application of effective manufacturing processes. Such products include the manufacture of standard fasteners from specialist materials but also special fasteners from standard materials. Fasteners can include clips for greenhouses, standard nuts and bolts and also the insulated fasteners that connect a vehicle's wiring loom with the heating elements that are embedded in car windows. Another good example would be the Acme range of whistles that are manufactured in Birmingham.

Over the last 40 years manufacturing in the UK has experienced reductions in employment combined with a process of continual restructuring (Gosney, 2011). These two processes have led to the formation of new forms of manufacturing and alterations in the spatial distribution of manufacturing activities. The on-going decline in British manufacturing has been dramatic and has led many commentators to argue that the UK has been transformed into an economy based on the provision of services rather than the production of manufactured products (Comfort, 2012). It is a popular misconception that manufacturing in the UK is 'either dead or soon would be' (PricewaterhouseCoopers, 2009: 6) or that the decline in British manufacturing 'has already deprived Britain of most of its manufacturing base' as British manufacturers 'have given up the ghost' (Comfort, 2012: 340).

Table 1. Current state of manufacturing sector (2010)

Indicator	Number	Significance (% whole economy)
Employment[a,b]	3,307,868	11.8
Enterprises[c]	266,363	14.1
Turnover (£million)[c]	566,410	18.2
GVA (£million)[c]	181,675	19.4
Export (£million)[d]	125,972.6	*Data not available*

Source: (a) BRES, 2010a (b) BRES, 2010b (c) ABS, 2010 (d) TOPSI, 2012

Table 2. Manufacturing sector performance (2008-10)

Indicator	Percentage Change
Employment[a,b]	-8.1
Enterprises[c]	-11.1
Turnover (£million)[c]	2.5
GVA (£million)[c]	0.9
Export (£million)[d]	4.7

Source: (a) BRES, 2010a (b) BRES 2010b (c) ABS, 2010 (d) TOPSI, 2012

Table 3. Top ten exporting industries by value (UK) (2010)

Industry (SIC)	Export value (£million)	Export Value Significance (% manufacturing total)	Export as proportion of turnover (%)
Chemicals, chemical products and man-made fibres (20)	20560.0	16.3	48.1
Automotive (29)	20255.9	16.1	44.0
Other machinery and equipment (28)	16743.0	13.3	48.6
Aerospace (30.3)	13683.4	10.9	53.0
Pharmaceuticals (21)	10580.1	8.4	58.1
Electrical and optical equipment (26)	10282.5	8.2	49.3
Fabricated metal products (25)	5497.2	4.4	17.9
Electrical equipment (27)	4978.0	4.0	37.2
Rubber and plastic products(22)	4343.8	3.4	21.7
Other manufacture (31,32)	593.2	0.5	27.3

Source: TOPSI, 2012

Manufacturing's contribution to employment is declining as services have grown at a much faster rate (Bryson *et al*., 2004). Nevertheless, output of the manufacturing sector has continued to grow, but at a much slower rate compared to services. This reflects a relative rather than absolute decline in manufacturing. This does not mean that the UK has been transformed into a service economy, but rather that services have begun to play a more important role in the economy. The growth in services reflects the development of new service products and markets. Services tend to be based on people-based skills and many service firms have found it difficult to develop productivity improvements (Bryson *et al*., 2004). It is important to appreciate that the growth of some service activities is directly linked to manufacturing; manufacturing increasingly requires inputs from many different types of service providers (Liversy, 2006; Bryson and Rusten, 2011).

The decline of manufacturing in the UK is based on a decline in employment rather than output. This has led to ‘jobless growth’ based upon productivity improvements. As a result, manufacturing is now less visible in apparently ‘post-industrial’ societies (Bryson *et al*., 2008; Christopherson, 2009, 2011). Thus, British manufacturing has been transformed through investment in new technology combined with process improvements that have reduced employment in the sector, but also contributed to a growth in output. These changes reflect an on-going process of structural readjustment and this adjustment takes two forms. First, there have been alterations in the composition of the economy, with a shift in employment and output towards finance and business and professional services (Bryson *et al*., 2004) and, second, there have been changes in the processes of production and the products made by manufacturing companies (Bryson, 2008; Bryson and Rusten, 2011). This report focuses on exploring the latter set of processes.

3. Manufacturing transformed: towards hybrid products and production systems

Manufacturing still matters within developed market economies. It is important not to underestimate the sophistication and knowledge-intensity of many manufacturing activities. Fingleton argues that, “those who advocate post-industrialism overestimate the prospects for post-industrial services, but they greatly underestimate the prospects for manufacturing. A major problem with the argument of post-industrialists is that they do not understand how sophisticated modern manufacturing truly is” (1999: 3). Manufacturing has been transformed. Recently, Livesey highlighted this transformation by arguing that:

> “… manufacturing has evolved but our understanding of it has not, manufacturing firms turn ideas into products and services. In today’s globally competitive landscape manufacturers are inventors, innovators, global supply chain managers and service providers. What was once seen just as production is now production, research, design, and service provision” (2006: 1).

Traditionally, manufacturing was understood as a relatively simple process that focussed on the transformation of raw materials into completed goods. This is no longer the case. Manufacturing has become technologically sophisticated, but it is also a production process that includes many knowledge-based services. It is important to remember that all production processes consist of a number of elements: manufacturing or fabrication, the provision of services that support fabrication and customer-targeted services. There is a danger that manufacturing is equated with production rather than conceptualised as one element of a much more complex production process. The production of products and services should be conceptualised as a process that consists of a complex and evolving blending of manufacturing and service processes. Some of these service functions directly support the manufacturing or fabrication process (production-related services, for example, design, testing, marketing, procurement, logistics, marketing etc) whilst others support the consumption process (product-related services, for example, servicing, aftercare etc.).

Manufacturing is becoming much more complex as technologically sophisticated products require increasingly complex blends of manufacturing and production- and product-related services. This process of blending is complicating the distinction between services and manufacturing. Many academics argue that manufacturing is experiencing a process of servitization (Vandermerwe and Rada, 1988) in which services are playing an increasingly important role in manufacturing (Neely, 2007). Nevertheless, manufacturing has always involved services including design, marketing and logistics. The role services played in the production and sale of manufactured products during the nineteenth century has been largely ignored (Bryson, 2010). The current debate over the on-going servitization of manufacturing has a long history. In 1995, Anderson and Narus noted that:

> “... suppliers have installed flexible manufacturing systems, created modular components that can be assembled in a wide variety of configurations, and designed platforms that can be shared by a family of products. But surprisingly, most manufacturers have focused only on the products themselves. They have largely

> ignored another element that plays a crucial role in differentiating a company's offerings and has a huge impact on costs and profits: services" (1995: 75).

This early account of the advantages of combining services with manufacturing suggested that services should be offered by companies as a set of flexible options and that many infrequently performed services should be repackaged as value-added options. More recently Neely has suggested that 'to survive in developed economies it is widely assumed that manufacturing firms can rarely remain as pure manufacturing firms. Instead they have to move beyond manufacturing and offer services and solutions, delivered through their products' (Neely, 2007: 2). This transformation in manufacturing towards the delivery of service solutions combined with manufactured products is not only a feature of manufacturing in developed or high-cost economies, but is part of the shift towards the development of new forms of advanced manufacturing or knowledge-based manufacturing. This process also reflects the on-going blurring of the divide between manufacturing and services; many manufacturing products are becoming similar to services and many services have been industrialised (Daniels and Bryson, 2002).

Servitization is only one stage in a much more complex process which involves the hybridisation of manufacturing and services to produce hybrid products. A hybrid product contains a complex combination of services and manufactured inputs and both sets of inputs are required for the product to function. Hybrid products can also be goods that have been converted to services. In this case, the manufacturer provides products to deliver a solution and, in many instances, ownership of the product is not transferred to the consumer. All production systems are hybrid systems that are based on a blend of service and manufacturing activities, but not all hybrid production systems produce hybrid products (Bryson, 2009).

It is important to note that each of the processes that are found within a hybrid production system may have a different geography. This is also the case with services that are part of hybrid products. This means that the future of British manufacturing rests on the development of two types of geography. First, there is the geography of the various functions that are part of a hybridising production system. Thus, design, logistics, research and development, fabrication and assembly may have different geographies. Second, a hybrid product requires manufacturing processes, but also service inputs that may come over the Web in the form of software upgrades or content or via distributed service centres. In this case, the service elements of a hybrid product may have a different geography that will be directly related to consumer demand. This means that British producers of hybrid products will establish service facilities in their core markets to support their products. It also means that non-British producers of hybrid products will have to establish facilities to provide services in core markets. For the UK, these service centres might be established in Britain or elsewhere in Europe. It is important to appreciate that the production and consumption of services often requires a shared language and culture and this means that the globalisation of service facilities has a very different set of drivers compared to manufacturing. One implication is that manufacturing firms based in Asia Pacific will have to establish both design and service centre in Europe. This represents a foreign direct investment opportunity for the UK.

Historically, manufacturing was considered to have one moment when profit was realised. Profit is created from the differential that must exist between the exchange value of the product (service/good/hybrid product) and the cost of production. It is not as simple as this - other profit moments exist that are directly related to the shift towards the creation of hybrid products. Production must be reconceptualised to take into consideration time and this results in a set of linked production exchanges; linked by the same customer and the identification of two or more profit moments in a transaction or a series of linked transactions. The first profit moment is based around the sale of the product whilst subsequent profit moments may be based around the provision of services (software upgrades, servicing, training etc). These exchanges can be considered as follows:

Time 1: Profit = Exchange value – (Manufacturing Processes (M) + Production-Related Services (PRS) + Product-Related Services (ProRS) + cost of finance + cost of labour + cost of material inputs).

Time 2: Profit = Exchange value + post sale product-related services (ProRS) – (cost of finance + cost of labour + cost of material inputs).

The point is that hybrid products provide their producers with more than one moment to obtain profit from a transaction. These can be considered as incremental profit creation moments that reflect the profits that can be acquired from developing and exploiting relational assets. This is an important point; modifications and improvements to the intangible expertise that is either incorporated directly into a hybrid product or to the intangibles that surround the product (training support, help desks, servicing, etc) provides additional revenue generating opportunities. They also represent moments during which employees and firms have to work, learn and develop new service-orientated competencies.

It is important to make the distinction between hybrid production systems and hybrid products (Bryson, 2009). It is possible for every production system to consist of complex combinations of manufacturing and service tasks, however not all products are hybrid products. Thus, a hybrid production system may not produce hybrid products. This highlights the fact that products can be placed along a hierarchy that ranges from hybrid products to products that exhibit all the characteristics of standard mass produced goods that do not contain service elements designed to develop a service relationship between the producer and the consumer. Low-value added production systems tend towards the production of standard goods whilst high-value added systems are more likely to produce hybrid products. A hybrid production system enhances the effectiveness of producing a standard good, but also has the opportunity to create hybrid products that capture additional value and results in a long-term relationship being formed between the producer and consumer.

Rolls-Royce is one of the most frequently cited examples of a firm that has shifted towards a service based business model. In the financial year 2006-07, 55% of this firm's revenues were derived from the delivery of services (Rolls-Royce, 2007: 15). In 1987 Rolls-Royce 'supported our engines in service by offering repair and overhaul arrangements which often failed to align our interests with those of our customers' (Rolls-Royce: 2007: 14). At this time, services were considered as a supporting set of functions rather than as an integral element within the firm's business model. Since 1987, Rolls-Royce has transformed itself into a provider of power rather than a provider of engines. A good example of this shift is the mission ready management solutions (MRMS ®) package by Rolls-Royce. MRMS provides the military with customised solutions that include total support packages and 'Power by the Hour'®. With the latter package, major airline and defence customers pay a fixed warranty and operation fee for the hours that an engine runs. Contract performance is measured against the performance of the fleet and in terms of ready for issue engine availability. Rolls-Royce offers three types of service solution. First, TotalCare is based upon an agreed rate per engine flying hour and this enables customers to engage in accurate financial forecasting. This package is designed for airline fleet and it transfers the technical and financial aspects of fleet maintenance from the customer to the service supplier. At the same time it converts Rolls-Royce into a service provider or more precisely a provider of hybrid products. Second, CorporateCare is intended for corporate and business jet customers and is designed to ensure that the aircraft is available when required and also may result in increased residual value. Third, MRMS is targeted at defence customers and provides them with engine management and maintenance to ensure 24/7 operational capability. These types of hybrid products have transformed Rolls-Royce from a company that designs and manufactures engines to a provider of turnkey engine power. To maximise profitability, Rolls-Royce must now focus on the effective management of an extended manufacturing value chain or its hybrid production system. This includes the design and development of engines, installation, after-sales maintenance, repair and overall services and parts availability and management.

The emergence of hybrid products and production systems has important implications for the ways in which manufacturing is tied locally. The linkages between a manufacturing firm and its locality are complex but include access to a set of supporting services that are critical for the production process. These services include design, product testing, research and development and all forms of consultancy. There is a critical set of relationships between services and manufacturing that are playing an increasingly important role in the competitiveness of manufacturing firms. The emergence of hybrid products is associated with the creation of distributed networks of facilities that provide customers with access to service support and service updates. More research is required into exploring the emergent geography of the service inputs that are an essential part of hybrid products. Service inputs may be delivered from a central location, for example software updates, or may require a distributed network of facilities. A distributed network may be owned and managed by the manufacturing firm or be owned by other companies who have a contractual relationship to supply the services that are part of a hybrid product. The requirement to provide service support means that foreign direct investment into the UK also includes foreign manufacturers establishing facilities to provide supporting services rather than manufacturing plants.

The on-going hybridisation of British manufacturing has many policy implications. It means that Britain's industrial policy must be simultaneously a service policy. This is a critical point. *The UK must develop an industrial strategy that is a production strategy that recognises the complex ways in which service and manufacturing tasks are combined in production systems.* A stand alone industrial or service strategy will not release the synergies that are developing between manufacturing and services and that have the potential to transform production.

The emergence of hybrid production systems and hybrid products has important implications for the *Standard Industrial Classification of Economic Activities* (SIC). This is a measure of economic activity constructed by the UK National Statistics agency to classify business establishments and other statistical units by type of economic activity. The on-going structural realignment being experienced by economies makes it impossible for governments to ensure that their national economic statistics are an adequate and current reflection of economic activity. This has always been the case. The UK SIC is a measure of economic activity, but essentially it is a backward looking measure; the SIC cannot be constantly amended to take into consideration on-going developments in economic activity. New functions are created and firms are established that deliver new types of products and services that do not fit with the existing SIC. It takes time for the SIC and academics to take into consideration these new types of economic activity and to alter the existing classification system. The United Kingdom's SIC has a long history of periodic change as it attempts to mirror the current structure of the economy. It is difficult for the SIC to cope with the changing nature of manufacturing that involves new hybrid forms of production; this represents an important weakness in the SIC. The SIC treats manufacturing and service activities as separate and does not acknowledge that manufacturing firms contain significant numbers of service workers.

Hybridisation has important implication for strategic policy intervention. Thus, manufacturing firms must be encouraged to increasingly distinguish between their 'captive market' which represents a firm's existing installed base of products and their non-captive market which includes customers that did not purchase a product from the firm. The captive market provides a firm with opportunities to sell additional service contracts, to persuade existing customers to upgrade, to co-innovate with strategic customers, to sell existing or new services and also to provide spare parts. A company's captive market provides many opportunities to develop new products by transforming existing customers into co-innovators. Many companies fail to maintain market share in their captive market as other companies develop products and service offerings. A firm that is not focusing on its captive market is underperforming and providing competitors with commercial opportunities. The concept of a company's captive market highlights the importance of developing manufactured products that include opportunities for the sale of attached or embedded services. It is worth noting that manufacturing companies that have performed extremely well in the current economic downturn have focussed on the sale of hybrid products – manufactured products that contain embedded services (Bryson, 2009; 2010; Bryson and Taylor, 2010; Bryson and Rusten 2011). This means that an economic downturn may be associated with a reduction in the sale of new manufactured products, but the company's captive market still provides opportunities to continue to sell additional services. For many producers of hybrid products consumers are locked-in to service contracts which provide companies with a continual flow of profits.

4. The evolving geography of manufacturing - from local to global

4.1 Relocation, restructuring, redistribution

Since the 1980s, two interrelated processes have been central to thinking about the emerging character and related geography of production systems. On the one hand, the on-going formation of a global economy and the development of complex global production systems and networks have played a central role in debates in fields as diverse as economics, sociology, cultural studies, business management, political science, regional science and geography (Hudson, 2001; Christopherson and Clark, 2009; Bryson and Rusten, 2011).

Extreme versions of the globalisation debate posit the end of geography as globalisation was considered to remove constraints related to distance and lead to the development of a borderless world (Ohmae, 1990; Friedman, 2005) in which many of the traditional inputs into production processes have become increasingly ubiquitous, or in other words available equally to all competitors regardless of location (Maskell and Malmberg, 1999). At this scale, the focus has been on the activities of transnational corporations and larger firms. On the other hand, globalisation debates have been tempered by a concern with regional economies (Christopherson and Clark, 2009). Much of this literature has focussed on the relationship between regions and globalisation and on understanding the drivers of local economic development and especially local agglomerations or processes of clustering (Taylor, 2010). Part of this academic debate has focussed on learning regions (Cooke and Piccaluga, 2004) and regional innovation systems (Asheim and Isaksen, 2002) and on trying to understand the difference that place makes to wealth creation focussing on both individuals in the form of local labour markets and firms.

The global and the regional approaches to understanding production reflect the operation of the same processes but operating at different scales. Developing a policy framework to encourage equitable global wealth creation is extremely difficult and is perhaps impossible. Such a framework could only be developed though complex supra-national negotiations; even if such a framework could be developed it would still advantage some countries over others. Regional policy is much easier to formulate as the region can be conceptualised as a coherent natural economic unit (Ohmae, 1995). Regions compete with one another. Such competition can involve subsidies intended to encourage firms to relocate facilities and to engage in foreign direct investment (FDI). Regions compete on the basis of their existing regional assets – skilled labour, historic associations, access to raw materials including funding, land, accessibility, etc. Some of these assets will be influenced by policies that can be developed and applied at the regional level, but some are controlled by national policies (taxation, legal system, etc) that regional policy making communities may only be able to influence and not control.

Regional economies are dominated by small and medium-sized enterprises (SMEs) and the majority of the working population will be employed by SMEs or by the public sector. Working for large transnational corporations is relatively unusual. There is an interesting paradox here. The academic literature tends to overemphasis the activities of transnational corporations and their ability to switch their activities between regions in the twinkling of an eye, but underemphasises the activities or importance of SMEs that tend to be relatively immobile. SMEs are included in discussions of the regional question, but predominantly in debates over clusters and clustering. What is required is a balanced approach to the regional question that explores the activities of transnational corporations, SMEs, but also micro-firms and even proto-firms (Rusten and Bryson, 2010).

Existing approaches to the regional question can be categorised into three types. First, are studies and policies based around the identification of local clusters (Taylor, 2010). This school of thought has a long history and in recent years has played a central role in policy formulation. There are major problems with the clustering literature as it places too much emphasis on local agglomerations compared to other ways in which production is organised in place and through space. Second, are the approaches based around understanding the development of knowledge and creative economies (Florida, 2005; Peck, 2005). Third, Christopherson and Clark have argued that the 'core characteristic of competitive regions is a willingness and capacity to absorb and adapt to the "three R's" of shifting firm strategies – relocation, restructuring, and redistribution' (2009: 35). These "three R's" refer to the relocation of production, the restructuring of work and the redistribution of costs and work. The argument is based on the assumption that 'the regional scale becomes the dominant scale for innovation and production through the demand for (skilled) labour' (2009: 34) while the global scale is driven by the demand for capital. Central to this argument is the role played by agglomeration economies in shaping regional geographies of production.

The emphasis placed on regional economies as the primary location for innovation and production is based on the appreciation that some of the factors of production or productive inputs (land, capital goods – tools and equipment, human capital – labour and skills, entrepreneurship) are regionally differentiated. Much of the debate focuses on the distinctiveness of regional labour markets. Labour markets are conceptualised as socially, economically and spatially constructed (Massey, 1984) through complex relationships between the state (national and regional), local institutions, trade unions and labour history, trade associations and lobbying groups and influential firms (Christopherson and Clark, 2009). The emphasis is on the importance of place-specific economic and non-economic factors in creating competitive advantage and in regional economic growth, but combined with the uncertainty associated with the mobility of productive capital. For policy-makers the question concerns the role regionally constructed assets, productive inputs, play in retaining and attracting capital investment that creates jobs and wealth.

The location of manufacturing was traditionally based on the availability of local assets. In his analysis of British industry Allen (1961) explored the development of three industry groupings: (1) metals, chemicals and engineering, (2) textiles, and (3) mining and quarrying. He noted that the geography of these industries was related to the period in which they developed and limitations related to the availability of factor inputs (land, raw materials, labour). Consequently, Britain's industrial centre of gravity during the nineteenth century was in the north given the availability of coal and in the Midlands and South Wales. He also reveals how certain places came to specialise in particular activities to exploit the benefits of local inputs combined with a focus on higher value products. The development of export markets facilitated this degree of localised specialisation. After the First World War, the tendency for industry to locate close to the coal fields was modified by new influences. These included the development of alternative sources of power, but also improvements in urban transportation led to the development of factories in the suburbs. An important influence on the geography of manufacturing after the First World War was the availability of cheaper sources of labour and taxation advantages. Localised specialisation of manufacturing led to the development of distinctive industrial assemblages. The machine tools industry developed in the neighbourhood of the industries they supported. Thus, textile engineering developed in Lancashire and the maritime industry developed on the North-east coast.

The relationship between localised inputs and the geography manufacturing led to the development of specialist areas that became dependent upon a narrow set of industrial activities. This permitted economies of scale to be developed, but it also reduced economic diversity within local economies. This reduction in diversity was a potential threat as competition for new technological developments had the potential to destroy an area's manufacturing base. The West Midlands developed into an integrated industrial complex based around the automotive and light engineering industries. This notion of integration is important as it highlights the relationship between a set of related manufacturing and service activities that developed to support a specialised industrial complex. From the mid 1960s, regions like the West Midlands experienced deindustrialisation in which manufacturing firms engaged in a period of consolidation driven by mergers and acquisitions, technological developments intended to increase productivity by reducing labour inputs and the relocation of activities from older industrial regions to newly industrialised economies (Bluestone and Harrison, 1982). Much of the academic and policy debate has focussed on the decline of manufacturing in the United Kingdom and the rise of a post-industrial service economy (Gershuny and Miles, 1983; Lash and Urry, 1993; Bryson *et al*., 2004). Nevertheless, the restructuring or deindustrialisation of British manufacturing that commenced in the 1960s did not herald the end of the industrial age, but rather the development of new forms of manufacturing.

4.2 Evolutionary approaches to understanding the geography of manufacturing

The development of evolutionary approaches in economics has provided an alternative perspective on understanding industrial location (Nelson and Winter, 1982). Evolutionary approaches try to understand why processes, industrial sectors or new forms of economic behaviour emerge and why and how they persist. The evolutionary approach has been applied to understanding the spatial evolution of newly emergent industries. These perspectives focus on understanding how new variants emerge and are selected and then diffused (Aldrich, 2004; Aldrich *et al*., 2008). In this perspective firm behaviour is guided by routines and the key issue is how new routines develop, diffuse and cluster. Diffusion mechanisms include spinoffs from existing firms that lead to the spread of new routines between organisations or various forms of spillovers.

Evolutionary economics stresses the importance of two processes that ensure that better routines become more dominant within an industrial sector. First, firms in the same sector will apply different routines and some of these will provide a firm or group of firms with enhanced competitiveness. More efficient firms will grow (Nelson and Winters, 1982) while firms with less effective routines will decline and even fail. Second, new routines that enhance the competitiveness of firms emerge and are diffused via processes of spinoffs, spillovers and imitation. Spinoff firms inherit the new routines from their parent companies. More effective routines can also be spread down value chains as companies work to improve their supplier base. In an analysis of the evolution of the British automotive industry Boschma and Wenting (2004) argue that agglomeration economies and spinoff dynamics played an important role in the spatial formation of this industry.

This analysis explores the evolution of this industry from 1895 and comes to three conclusions. First, during the initial development of the industry some regions contained assets or resources that contributed to the formation of the new industry. This is an important point. New industries can be established in older industrial regions by applying existing knowledge and routines to the development of new products and services (Christopherson, 2009, 2011). Second, a few very successful automotive firms created a significant number of spinoff companies and spinoffs located in the automotive cluster around Coventry performed better than spinoffs located elsewhere. Third, entrepreneurs who had prior experience in an existing successful automotive firm were more successful compared to inexperienced entrepreneurs.

Diffusion of routines occurs via processes of inter-organisational learning (Klepper, 2002). This can take many forms (Bryson, 2007). First, the movement of employees between firms can lead to a diffusion of new routines. Second, public policy can try to identify new routines that have emerged in an industry and to spread these innovations via various forms of public policy intervention. Third, consultancy firms can identify new routines that have emerged in one of their client companies and spread these routines to other firms. Fourth, spinoffs from a parent company or supply chain interventions can spread new routines. Fifthly, knowledge can spillover between firms that are co-located or clustered. Co-location provides opportunities for firms to learn from one another via processes of observing, recruiting staff who have worked for local competitors, monitoring competitors and imitation (Malmberg and Maskell 2002). The evolutionary perspectives highlight the importance of localised agglomerations as contributing to the diffusion of new routines between firms. Nevertheless, it is important to note that over reliance on localised learning can produce various forms of path-dependency or lock-in and when this occurs learning is restricted to available local knowledge.

The evolutionary approach highlights the importance of the spread of new routines between firms. This diffusion can occur covertly with firms in an industrial sector monitoring and observing one another without any direct interaction. The firms can be co-located or dispersed with monitoring occurring at trade exhibitions, from exploring competitors' websites and catalogues. Reverse engineering also occurs with firms purchasing and dismantling competitors' products (Bryson and Rusten, 2011). Geography or agglomeration economies do not play a significant role in these forms of knowledge spillovers. Routines can also spread through various forms of social connectedness as social networks can play a valuable role in the transmission of tacit or experiential knowledge. Such social interactions tend to be geographically localised and this suggests that knowledge spillovers will increasingly occur within a region via processes of co-location.

There is a tension in evolutionary accounts of industries. There is an emphasis on the diffusion of routines through localised interactions that are facilitated by social relationships. Nevertheless, the developing global economy and, in particular, the migration of skilled labour provides opportunities to spread routines between different regions and countries. It is also worth remembering that transnational corporations are able to acquire routines from many different places and to spread these throughout the firm.

5. Costs versus specialised factors of production: the role of place-based inputs

The emphasis placed by Christopherson and Clark (2009) on the three 'Rs' is an approach to understanding the competitiveness of regional economies that highlights price-based competitiveness founded upon cost control. Cost control is critical for the competitiveness of manufacturing companies. Nevertheless, manufacturing companies are able to compete on more than just price, but also a set of factors that are not directly related to price.

These factors may represent a unique set of advantages that provide a firm with monopolistic competition amongst parts of their market. In traditional economics price is considered as the mechanism that is used to calibrate the value of things and to co-ordinate the relationship between producers or suppliers and consumers. Price is a crude measure of differentiation and it is also a measure that is easily copied. At a very simple level, price is used to identify differences and similarities between products and also is a way for consumers easily to differentiate between products. Price and money transforms products into commodities; things that are removed from their social context. In Simmel's classic account of money, price or money imposes a 'merciless objectivity' (Simmel, [1907] 1990: 431) on consumption as it transforms 'all qualitative distinctions between [things in to] the distinction of "how much"' (ibid.: 127). This is too much of a simplification. For some transactions consumers' depend predominantly on price to differentiate between products that have similar characteristics. An excellent example would be utility providers – one kilowatt hour of gas is the same as any other and is only differentiated by price and price provides consumers with 'merciless objectivity'. Nevertheless, many products are purchased by trading-off price against a series of non-price and price related characteristics. A company can develop a 'unique' product by formulating a distinctive bundle of price and non-price based product characteristics (Cagliano, *et al*., 2005; Bryson and Rusten, 2011). In many cases, a product's capabilities (characteristics, design) or personality (image, design association, history, consumer's former association with the product etc) and producer's organisational personality (history, brand, country of origin) may be more important than its price. An excellent example is J. Hudson & Co. (Whistles) Ltd, Birmingham, the oldest and largest manufacturer of whistles in the world. This company was established in the 1860s and has since then engaged in a continual process of innovation. It manufactured the whistles that were used on the Titanic and also for the London Olympic Games. Its sells its whistles under the brand of ACME and this provides the company with an indirect and serendipitous association with the Road Runner cartoon character and the cartoon ACME company that can manufacture any product. The company blends cost control with impossible to copy non-price based factors related to heritage, tradition, brand, the provision of innovative sound solutions and 'made in England' associations. These non-price based associations ensure that the company continues to manufacture in the UK and makes it difficult for its overseas competitors to copy the company's business model. Aston Martin's close association with James Bond 007 is another excellent example of a serendipitous association that provides the company with inimitability.

The importance of non-price based characteristics in the market place provides manufacturing companies located in high-cost locations with an opportunity to develop and maintain product and corporate inimitability. The danger is that companies located in low-cost production locations might eventually be able to imitate these strategies. Companies located in high-cost locations must withdraw from price-based competition and compete on other variables related to design, brand, nearness to market, speed, customisation and the provision of services (Bryson *et al*., 2008; Bryson and Taylor, 2010; Bryson and Rusten, 2011). This is to argue that firms and regions compete on the basis of a distinctive set of capabilities. This is to shift the focus away from explaining 'productivity and competitive advantage in terms of measured inputs of factors of production, ignoring the mediating role of capabilities. Critically, it focuses on the role of design in economics.

There are two ways to make more with less: improve resource allocation and redesign the process' (Best, 2001: xvi). This is to recognise that the future competitiveness of manufacturing in the United Kingdom depends on blending effective resource allocation with the development of capabilities that provide non-price sources of distinctiveness. The history of production reflects a constant tension between continuity and change. Regions and counties possess technological, management, price and non-price based advantages and these provide continuity. However, continuity is the basis of economic decline unless firms and their products and services experience a continual process of change. This is to highlight the importance of continual product and process improvements.

6. The geography of British manufacturing: a sector based analysis

The experience of British manufacturing over the period 2008 to 2010 highlights continued productivity improvements. Thus automotive (SIC 29) exports increased by 13.8% (TOPSI, 2012), but employment declined by -21.8% (BRES, 2010a & b). Similarly the export of leather products (SIC 15) increased by 45.8% (TOPSI, 2012) whilst employment declined by -19.0% (BRES, 2010a & b). In only two areas of manufacturing was export growth associated with employment growth. Other transport (SIC 30) experienced an increase in employment growth of 46.1% (BRES, 2010a & b) and in exports of 43.9% (TOPSI, 2012) while exports of wearing apparel (SIC14) increased by 34.1% (TOPSI, 2012) and employment by 9.9% (BRES, 2010a & b). Different sectors of manufacturing are experiencing different forms of growth. This includes 'jobless growth' driven by productivity improvements related to process and product innovations, and also sectors that are experiencing limited employment growth. Jobless growth is particularly significant in sectors that make important contributions to GVA and these include food (SIC 10), automotive (SIC 29), optics (SIC 26), chemical products (SIC 20) and pharmaceuticals (SIC 21). This highlights the heterogeneity or diversity of manufacturing. This diversity is also found in the evolving economic geography of manufacturing.

The focus of this analysis is on exploring the economic geography of manufacturing in the UK. This is achieved by using Location Quotients (LQ). The Location Quotient is a well known and used analytical tool for identifying concentrations of economic activity by sector and place (Klosterman, 1990; Isard *et al*., 1998). This LQ compares a local economy to a reference economy and in the process attempts to identify specialisations in the local economy. The data comes from the *British Register and Employment Survey* (BRES, 2010a). The location quotient technique is based upon a calculated ratio between the local economy and that of the reference unit. LQs are generated by calculating the percentage of the national total (employment, R&D expenditure etc) of a particular group of workers or firms found in a given area, and the percentage of the national total for all workers or firms found there. The former is then divided by the latter[1]. A quotient greater than 1.00 means that the area's labour force is more biased towards that particular group while a quotient of 2.0 means that the area has twice as many people working in the sector as expected and a quotient of 0.5 means half as many. The value of LQ scores varies according to the spatial scale used for the measurement. Thus, an analysis of the West Midlands would identify activities that are strongly clustered in the West Midlands, but may be weakly clustered in any national analysis. It is important that a comparative analysis using LQs uses the same spatial scale. LQ scores provide one indicator of the degree of localisation or otherwise of a particular activity in a given area.

1

$$\text{Location Quotient} = \frac{\text{Regional Employment in Industry A in Year T}}{\text{Total Regional Employment in Year T}} \Big/ \frac{\text{National Employment in Industry A in Year T}}{\text{Total National Employment in Year T}}$$

The analysis is based around the following classification of LQ scores based on employment:

<1	No localisation (underrepresented compared with England)
1-<1.5	Weak localisation
1.5-<3.0	Strong localisation
3.0-<6.0	Very strong localisation
6.0+	Extreme localisation

British manufacturing has two types of geography: localised concentrations or clusters or more ‘footloose’ or distributed industries.

Historically, the geography of manufacturing is related to the location of factor inputs (raw materials, energy, labour, etc). Once an industry was established in an area a localised concentration tended to form as new firms were established as spin offs from existing firms and foreign firms established facilities in the area. This implies that a set of localised structures and institutions form that enhance the stickiness of some economic activities. Such structures include a community of firms, the presence of an active supply chain, supporting services, a localised labour market, a place with a reputation for an economic activity and the presence of trade association and professional bodies. More traditional industries tend to have geographies that are closely related to localised concentrations. These localised concentrations are identified by the LQ analysis that reveals that such localised industries include basic metals (SIC 24), shipbuilding (SIC 30.1), tobacco products (SIC 12), computer facilities (SIC 15), computer facilities management (SIC 62.03), coke products (SIC 19), aerospace (SIC 30.3), leather products (SIC 15) and wearing apparel (SIC 14) (Table 4). All these sectors exhibit extreme localisation with location quotients above 6.0. The clustered nature of much of this activity reflects the historical evolution of these industries. This is partly driven by path dependency as previous decisions have determined the current location of activities. These extreme concentrations reflect both history and path dependency but also the existence of concentrations of skilled labour and localised research and innovation ecosystems that play an important role in the emergence of new industrial activities. It is also important to appreciate that an established or even mature industry can be transformed through the application of new technologies and innovations. A good example is the on-going evolution of parts of the textile industry. This is shifting away from the production of traditional woven fabrics to the development and manufacture of technical textiles – textiles that perform many different functions. This example is driven by alterations in customer demand, but also by the relationships between firms and the research and innovation community.

The more footloose industries are computer, electronic and optical equipment (SIC 26), electrical equipment (SIC 27), other machinery and equipment (SIC 28), other manufacture (SIC 31.32), specialised design (SIC 74.1), food products (SIC 10) and wood products (SIC 16) (Table 4). These more footloose sectors tend to be much more heterogeneous and/or have developed more recently. It is important to remember that many of these industries work together to form production complexes. A good example is specialised design that is distributed or more footloose and has relatively low levels of localisations, but with some concentrations in the South East (Figure 1).

Table 4 Spatial distribution of manufacturing sub-industries at the regional scale (NUTS2) (2010) (UK).

Concentrated industries:

Industry	Total Employment	Highest LQ
Basic metals (24)	69895	16.75
Shipbuilding (30.1, 33.15)	37760	15.55
Tobacco products (12)	1705	14.72
Computer facilities management (62.03)	938	13.49
Coke, petroleum and nuclear fuel (19)	9819	11.32
Aerospace (30.3, 33.16)	100478	9.18
Textiles (Leather and related products) (15)	7847	8.60
Textiles (wearing apparel) (14)	39629	8.18
Beverages (11)	36812	6.28
Textiles (including technical) (13)	60926	5.27

Footloose industries:

Industry	Total Employment
Computer, electronic and optical products (26)	126796
Electrical equipment (27)	85350
Machinery and equipment n.e.c. (28)	179389
Other manufacture (31,32)	161509
Activities of head office (70.1)	190393
Specialised design (74.1)	38902
Other professional services (74.9)	83892
Office administrative and support activities (82.1)	20981
Food products (10)	353907
Wood and wood products	74576

Based on ratio of strong localisation to under-represented and the value of LQ. NOTE: Pharmaceuticals, automotive and chemicals have several smaller clusters.

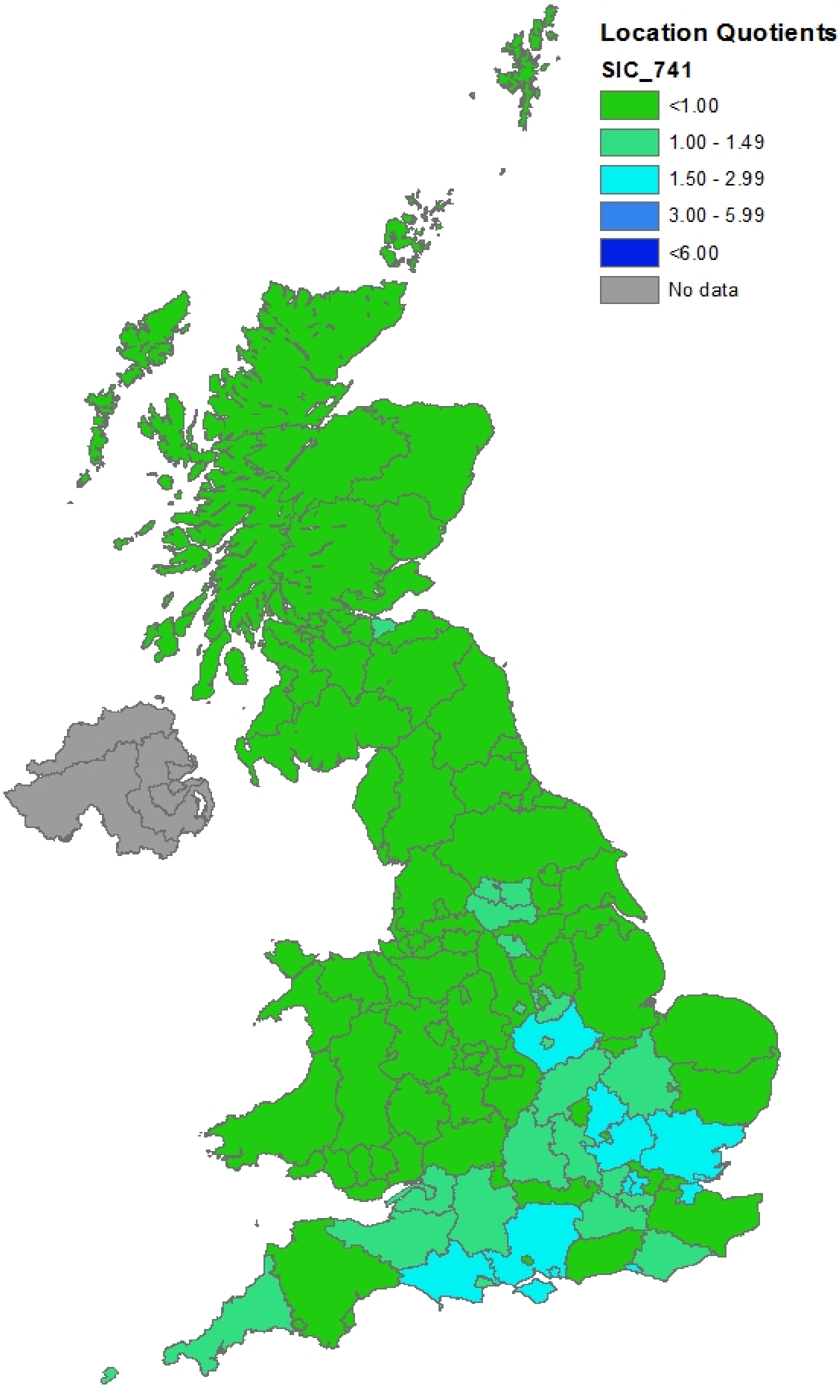


Figure 1. Localisation of employment in specialised design activities industry (SIC 74.1) at the county scale (NUTS3)

The industry's geography is related to the needs of local customers combined with concentrations of activities in the South East that provide inputs to British firms, but also export their services. In contrast, technical testing of products (SIC 71.2) has localised concentrations that mirror some of the extreme localisations of mainstream manufacturing with concentrations in the West Midlands (automotive), Cumbria (Basic Metals, Shipbuilding) and Merseyside (Chemicals, Pharmaceuticals, Other Non-mineral manufacturing). Research and Development (R&D) (SIC 72.1) has a similar geography with localisations in Bristol (Aerospace), North Yorkshire (Food Products, Beverages) and Cheshire (Coke Products, Chemicals and Pharmaceuticals and Automotive).

Specialised design, R&D and other technical services have localised concentrations in London and the South East, but technical testing is either under-represented in these areas or has only very weak concentrations.

This analysis will now focus on **nine manufacturing sub-industries** that are important for strengthening the UK's export base and are also sectors involving high-value added manufacturing (Table 3). These nine sectors have been identified through an analysis of a much broader group of manufacturing sub-industries in the UK. This analysis was focused on identifying sectors that are currently significant exporters. It was also important to identify sectors that have different types of geography – from sectors that are clustered to sectors with much more dispersed geographies. All the sectors make important contributions to the UK in terms of their share of employment of GVA and some are more mainstream sectors whilst others are niche sectors. These industries are: 1) Food Products (SIC 10), 2) Fabricated Metals (SIC 25), 3) Other Machinery and Equipment (SIC 28), 4) Automotive (SIC 29), 5) Computers, Electronic and Optical Equipment (SIC 26), 6) Chemicals and Chemical Products (SIC 20), 7) Aerospace (SIC 30.3, 33.16), 8) Pharmaceuticals (SIC 21), 9) Wearing Apparel (SIC 14).

6.1 Food products

First, the manufacture of food products (SIC 10) is spread throughout the UK, but there is significant localisation of fish products in Scotland (SIC 102) and noticeable underrepresentation in the West Midlands and the South East (Figure 2).

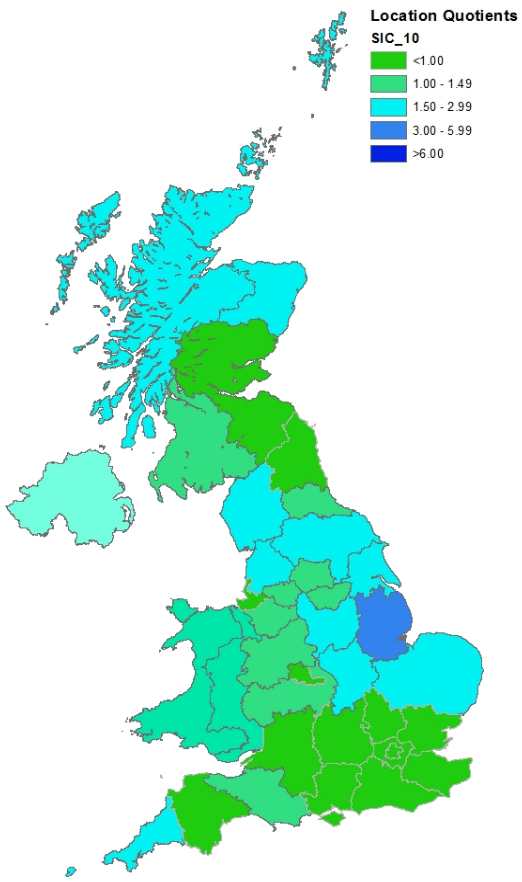


Figure 2. Localisation of employment in food products industry (SIC 10) at regional scale (NUTS2)

The LQ analysis of the food industry hides concentrations related to local specialisations. There is localisation, for example, in London of the manufacture of vegetable and animals oils (SIC 104) and dairy products (SIC 105) and in the South East for the manufacture of grain mill products (SIC 106) and bakery products (SIC 107). It is worth noting that food manufacturing is the largest contributor to employment, but employment declined by -1.7 % between 2008 and 2010 while exports increased by +34.7%. The production of food products represents a valuable opportunity to combine cost control with non-price based aspects of the product related to quality, heritage brands, locally sourced foods, associations with British manufacturing and quality.

6.2 Fabricated metals

The fabricated metal industries are strongly localised in the West Midlands, Derbyshire, South Yorkshire, Durham and Northeastern Scotland (Figure 3). There is a strong concentration of forging, pressing and stamping (SIC 255), the treatment and coating of metals (SIC 256), the manufacture of cutlery, tools and general hardware (SIC 257) and the manufacture of steel drums (SIC 2591) in the West Midlands. It is worth noting that an agglomeration or a cluster in this industry enhances the performance of a firm, but does not provide a competitive advantage. Thus, research on agglomeration in the US metalworking sector has shown that ‘location in an agglomeration, however, appears, to be neither necessary nor sufficient for enhanced performance or successful collaboration’ and that ‘firms may be advantaged by seeking out better-performing distant suppliers rather than being constrained to the potential suppliers available locally’ (Appold, 1995: 52).

The location of other fabricated metals not elsewhere classified (SIC 25.99) has a different geography to the fabricated metal industries (SIC 25). Both have concentrations in the East and West Midlands but the not elsewhere classified (N.E.C) group has extreme localisations in the South East region (Figure 4). The N.E.C grouping is interesting as this includes nascent activities that may represent new industrial activities. These locations correlate with concentrations of specialised sub-industries including the manufacture of steam generators (SIC 253), the manufacture of weapons and ammunition (SIC 254), the treatment and coating of metals (SIC 256) and the manufacture of cutlery, tools and general hardware (SIC 257). This is an important policy point as the presence of a linked supply chain is an important element of this sector’s competitiveness. Thus, maintaining the quality and diversity of the supply chain within the UK is critical for the long-term competitiveness of this sector.

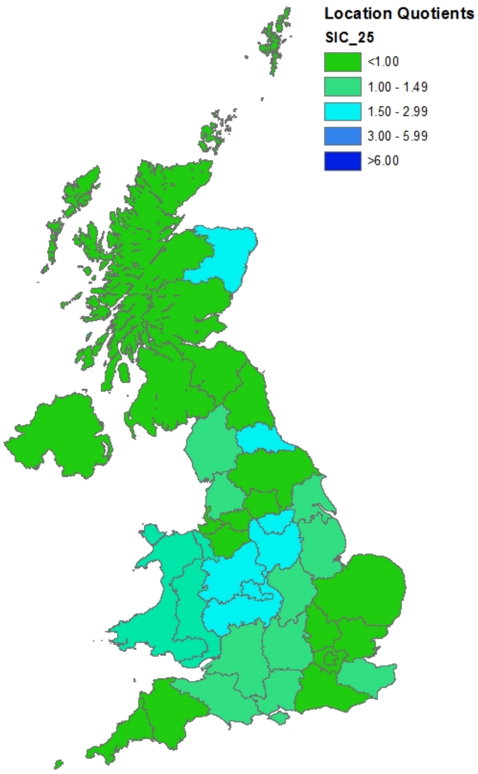


Figure 3. Localisation of employment in the fabricated metal products industry (SIC 25) at the regional scale (NUTS2)

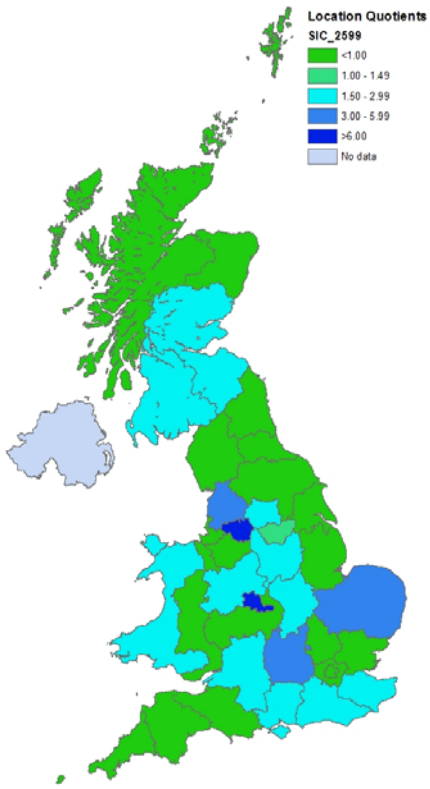


Figure 4. Localisation of employment in the other fabricated metals n.e.c. industry (SIC 25.99) at the regional scale (NUTS)

6.3 Other machinery and equipment

Overall, the production of other machinery and equipment (SIC 28) does not have particularly strong concentrations of employment (Figure 5).

Nevertheless, sub-industries have strong localisations in the Midlands. There is a relationship between the location of the production of metal forming machinery (SIC 28.4) and other special-purpose machinery (SIC 289) with the production of fabricated metals (SIC 25) and the automotive industry (SIC 29). The manufacture of general purpose machinery (SIC 281 and 282) has a concentration of employment on the south coast and in the South East region. This sector highlights that this is both a localised and dispersed sector, but it is also closely related to the concentrations of metal-based industries in the West Midlands and elsewhere.

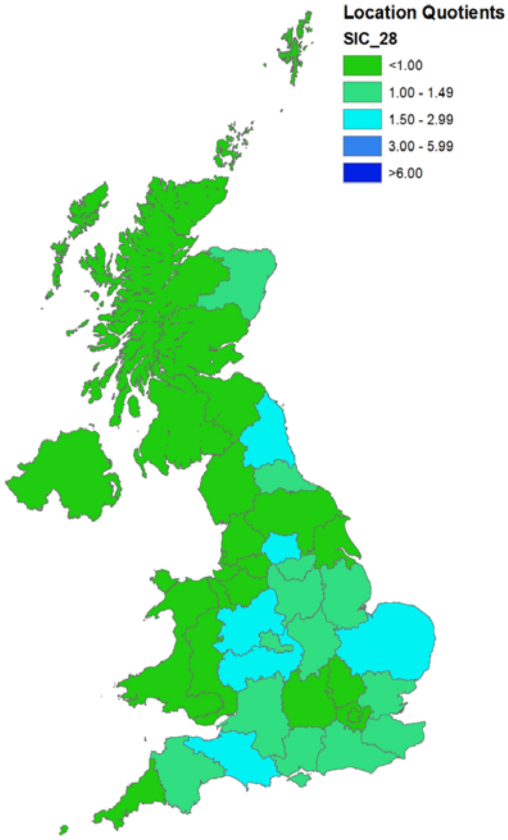


Figure 5. Localisation of employment in other machinery and equipment n.e.c. industry (SIC 28) at the regional scale (NUTS2)

6.4 Automotive industry

The automotive industry is strongly localised in the West Midlands, Cheshire, Northumberland and Tyne and Wear (Figure 6). These concentrations are dominated by the location of large businesses involved in the manufacture of motor vehicles in places like Solihull (Land Rover), Sunderland (Nissan) and Cheshire (Bentley). The West Midlands has a strong localisation for all sub-industries involved in the automotive sector, but the manufacture of parts and accessories (SIC 2932) is particularly located here. Northern England has a strong concentration of employment involved in the manufacture of automotive body parts (SIC 2920). All sub-industries involved in the automotive sector are notably under-represented in the south of England with the exception of Oxfordshire (LQ 4.52 in SIC 2910 – the manufacture of motor vehicles).

The importance of agglomeration for the automotive industry reflects many of the insights provided by evolutionary approaches to understanding the geography of manufacturing (Boschma and Wenting, 2004). Further detailed research would also be required to understand the relationship between the automotive industry and the provision of linked and embedded services. The automotive industry requires complex supply chains and many of these supply chains are localised as parts having to be transported to assembly plants on a just-in-time basis. Supply chains highlight the interconnected nature of manufacturing. This means that a reduction in capacity, for example in the basic metals or fabricated metals industry, could have a detrimental impact on the future of the British automotive industry. It is critical that the UK maintains the quality and quantity of firms that have the capability to supply automotive parts. Any further decline of the automotive supply chain will have important consequences for the long-term future of the UK automotive industry.

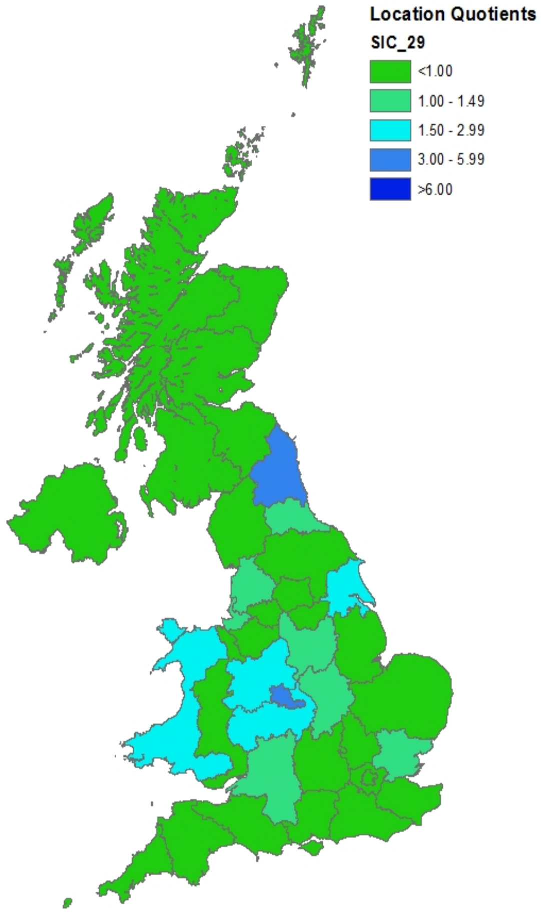


Figure 6. Localisation of employment in the automotive industry (29) at the regional scale (NUTS2)

6.5 Computers, electronic and optical equipment

The manufacture of computers, electronic and optical equipment (SIC 26) does not have a geography based on significant employment concentrations (Figure 7).

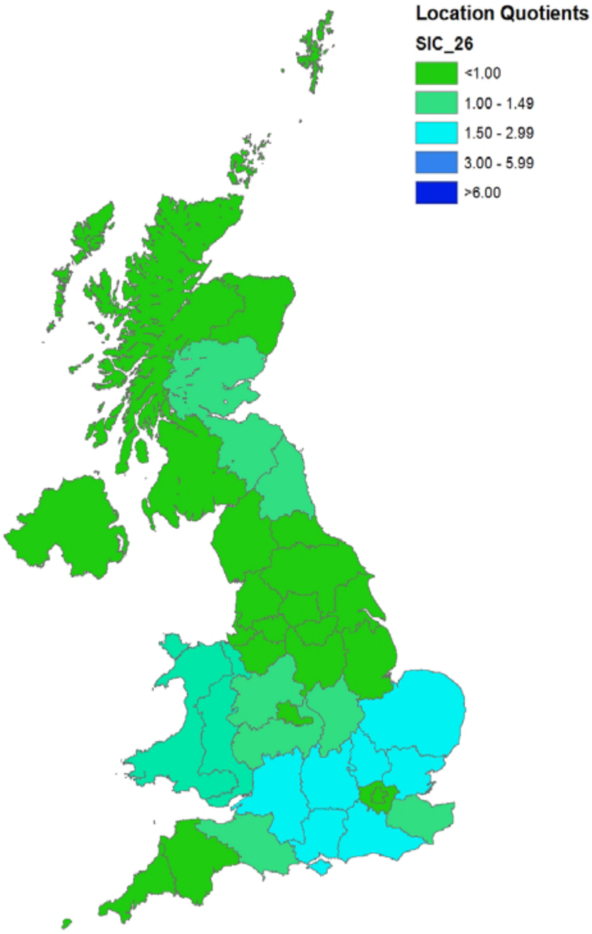


Figure 7. Localisation of employment in the computer, electronic and optical equipment industry (SIC 26) at the regional scale (NUTS2)

The industry is focused on the South East, with weak concentrations throughout South England, Wales and eastern Scotland, but the industry is under-represented in Northern England and London. Sub-industries in this sector have a similar geography, but there are separate concentrations in northern England related to electrical components (SIC 261) and communication equipment (SIC 263), with Tyneside and Sunderland having a concentration of employment in electronics (SIC 264). The photonics industry or the manufacture of optical and photographic equipment, magnetic and optical media (SIC 2870 and 2680) has a pattern of employment focused on southern England, Eastern Scotland and northern and southern Wales (Conwy and Denbighshire and Gwent Valleys). There is also an extreme concentration in Glasgow (LQ 13.13) and strong concentrations in Leicestershire (LQ 4.41), Somerset (LQ 4.31) and Cornwall (LQ 1.64).

6.6 Chemicals and chemical products

Just over 16% of manufacturing exports are in chemicals and chemical products and 48.1% of the turnover of this industry was exported in 2010. The chemical products industry (SIC 20) is strongly localised in the Tees Valley and Durham. There is extreme localisation of basic chemicals (SIC 20.1) in the North East, but also in Cheshire and East Merseyside, but under-representation in southern England and Wales (Figure 8). Nevertheless, there are strong localisations in southern England for the production of more specialised chemical products including the manufacture of paints, varnishes and similar coatings (SIC 203), the manufacture of soaps and detergents, cleaning and polishing preparations (SIC 204) and the manufacture of man-made fibres (SIC 206). The manufacture of other chemicals not elsewhere categorised (SIC 2059) has a different geography with concentrations in the South East and strong localisations in the North West (Figure 9). The not elsewhere categorised SIC code may reflect new innovations in the chemicals industry that may develop into important new sub-industries. The chemical industries are relatively energy intensive and this implies that the cost of energy will play an important factor in the continued success of this industry within the UK.

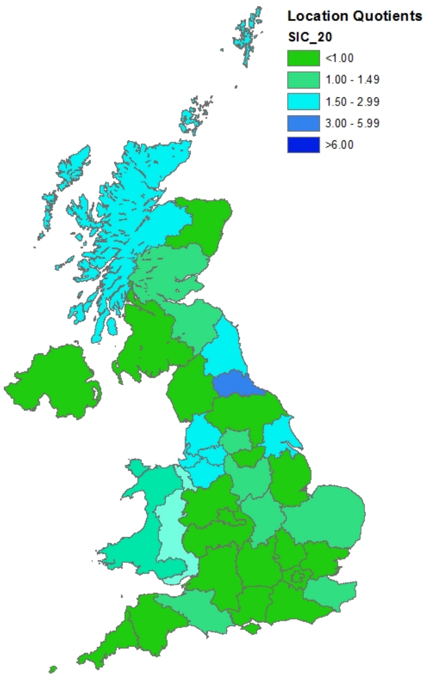


Figure 8. Localisation of employment in chemical products (SIC 20) at the regional scale (NUTS2)

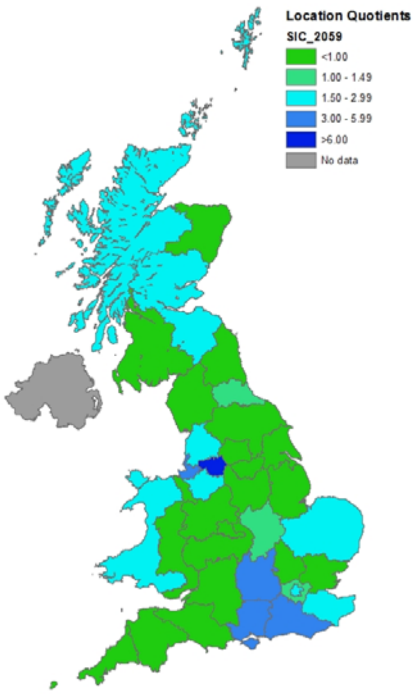


Figure 9. Localisation of employment in other chemical products n.e.c. (SIC 2059) at the regional scale (NUTS2)

6.7 Aerospace

The aerospace industry accounts for 10.9% of manufacturing exports and 53.0% of this industry's turnover are exported. In 2010, 81,815 people were employed in the manufacture of air and spacecraft and 18,659 involved in repair and maintenance. The aerospace industry is extremely localised in Lancashire and has strong localisations in Derbyshire, East Wales, Bristol and the Isle of Wright (Figure 10).

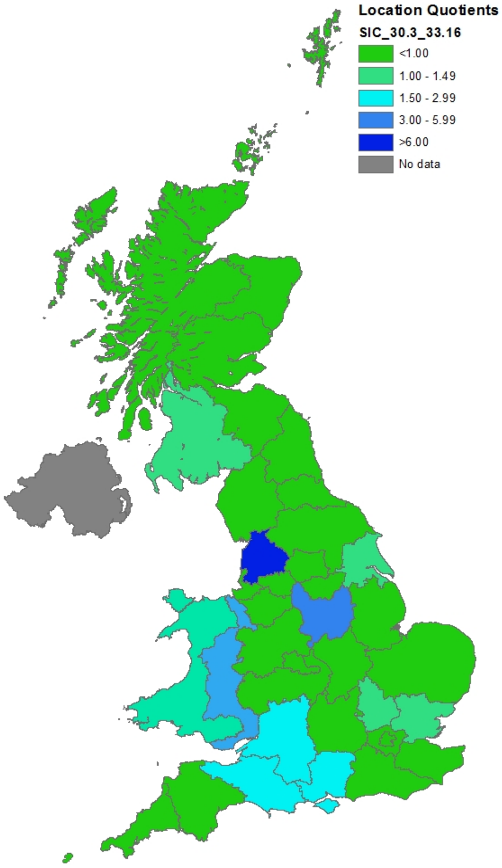
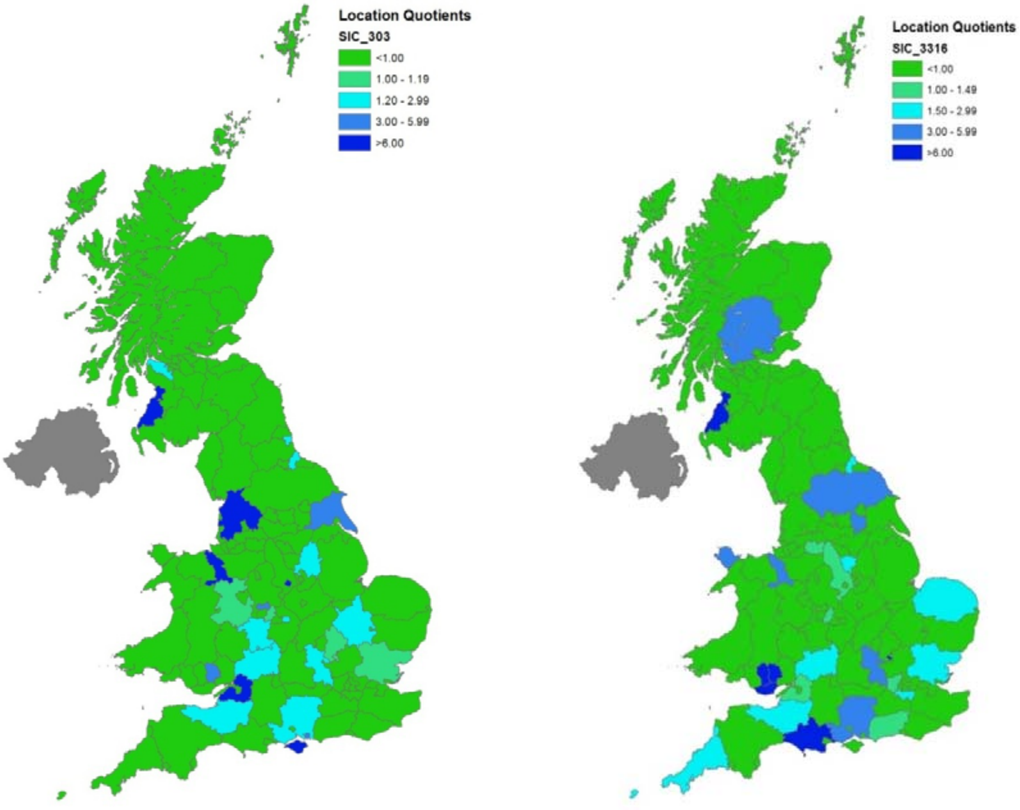


Figure 10. Localisation of employment in aerospace industry (303, 3316) at the regional scale (NUTS2)

It is one of the most localised manufacturing sectors in the United Kingdom. Aerospace sub-industries have different localisation patterns with the only area to have the same extreme localisation being South Ayrshire. The repair and maintenance of aircraft (SIC 33.16) has localisations close to, but not the same as the manufacture of aircraft (SIC 30.3) (Figure 11a & b). Extreme locations are found in Luton (LQ 14.08), Dorset (LQ 9.29), South Wales (16.41), Gwent valleys (LQ 8.44) and Cardiff and the Valley of Glamorgan (LQ. 8.92). These support strong localisations in the Home Countries, Isle of Wight and the Bristol area. Aerospace is an extremely technical industry which requires a skilled workforce. Linkages to universities are critical for continued technical innovations. On-going developments in production technologies are beginning to be applied to this sector, for example 3D printing as are developments in new materials. The continued development of this industry in the UK requires continued investment in new materials and technologies and especially innovations that will increase fuel efficiency and reduce noise.



(A) **(B)**

Figure 11. Localisation of employment in (A) the manufacture of aircraft and spacecraft (SIC 303) and (B) the maintenance and repair of aircraft and spacecraft (SIC 3316) at the county scale (NUTS3).

6.8 Pharmaceuticals

The pharmaceuticals sector accounts for 8.4% of exports of manufactured products and 58.1% of turnover is exported. As a whole the industry (SIC 21) does not have any extreme concentrations, but there are strong localisations in Bedford and Hertfordshire (LQ 3.32) and Cheshire, Merseyside and East Yorkshire (Figure 12).

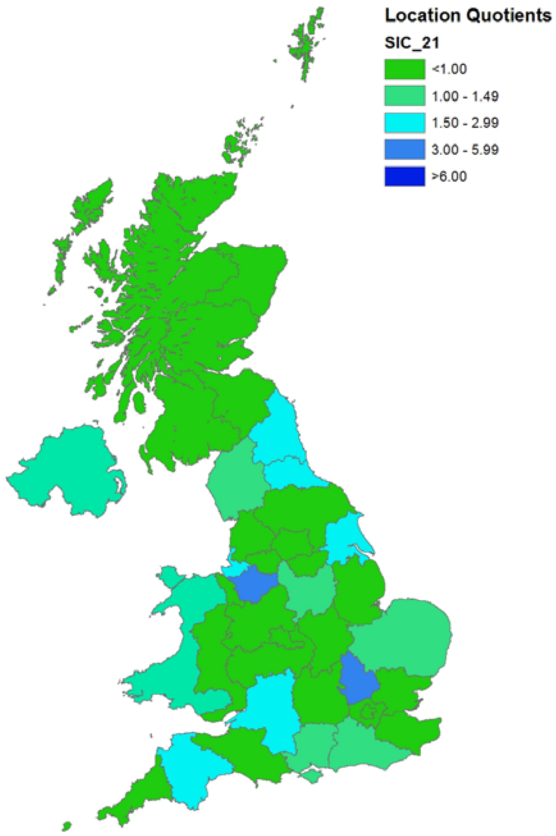


Figure 12. Localisation of employment in the pharmaceuticals industry (SIC 21) at the regional scale (NUTS2)

The industry has weak concentrations throughout the country, but is under-represented in Scotland. The manufacture of basic pharmaceutical products (SIC 2110) is extremely concentrated in parts of the North West of England and Yorkshire (Figure 13a). It is worth noting that the industry employed only 5696 in 2010 and the concentrations perhaps reflect the location of large single businesses. The manufacture of pharmaceutical preparations involves 34,153 people (SIC 2120) and there are extreme concentrations in the North East (Figure 13b). This sector is research intensive and there are important regulatory controls on the industry related to the management and regulation of research and development and testing. The sector requires continual innovations and these can be facilitated by the development and maintenance of research relationships with universities.

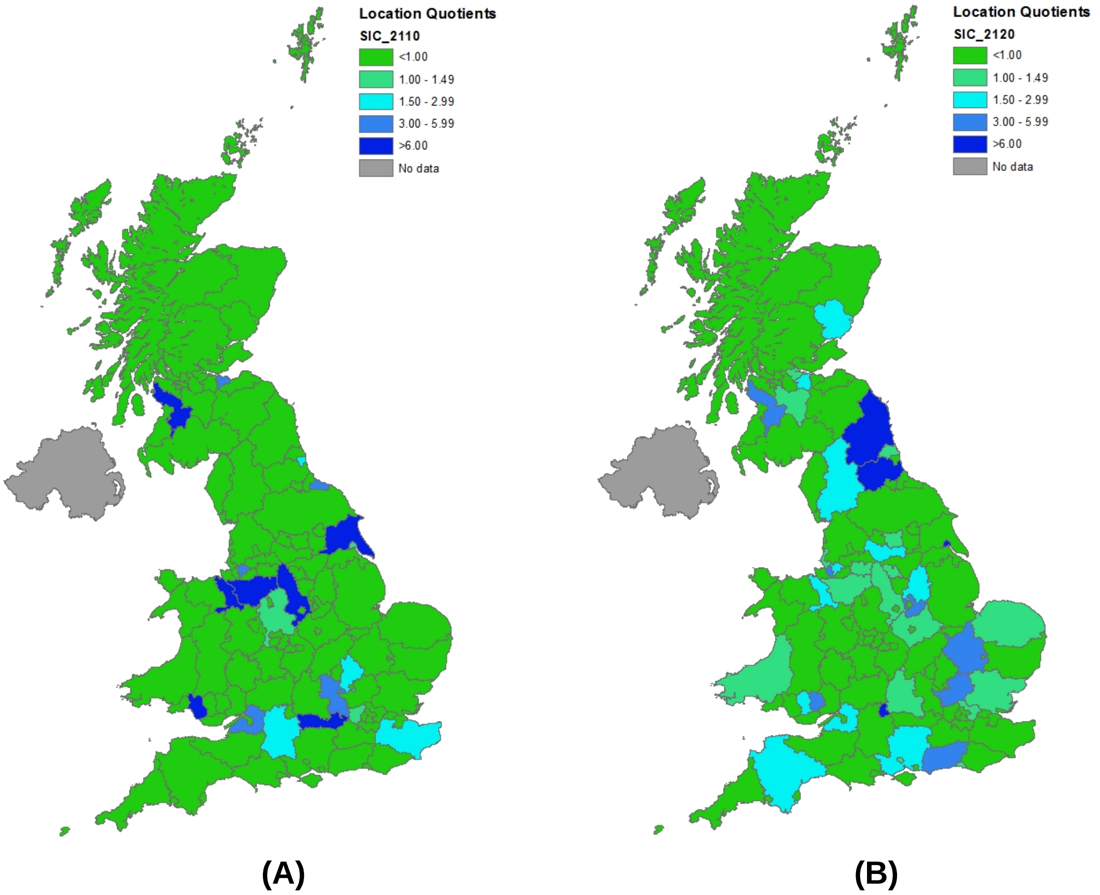


Figure 13. Localisation of employment in (A) the manufacture of basic pharmaceutical products (SIC 2110 and (B) the manufacture of pharmaceutical preparations (SIC 2120) at the county scale (NUTS3).

6.9 Wearing apparel

The manufacture of wearing apparel (SIC 14) employs 1.2% of all people involved in manufacturing and between 2008 and 2010 employment grew by 9.9% and exports by 34.1%. The industry is concentrated in the East Midlands and in particular Leicestershire, Rutland and Northampton (LQ 8.2) (Figure 14). There is a concentration of the manufacture of knitted and crocheted apparel (SIC 143) in the Scottish Highlands. Textile production is altering as new technological developments have led to the creation of high-value added ‘technical textiles’ (SIC 13) that focus on innovation in the functions performed by textiles. This is a growing emergent sector that provides textile solutions for many other industries including automotive and aerospace applications, medical technologies (textile stents), protective clothing (radiation and heat protection), geotextiles, sportswear (sun protection, wicking fabrics) and protective textiles (bulletproof clothing, stab protection). The definition of technical textiles is complex. Further research is required to explore the contribution this technology is making to the British economy. This new technology also includes the introduction of technical nonwovens or composites. Developments in technical textiles are revitalising the textile industry and transforming it from a mature to highly innovative sector (Clark, 2013). The development of technical textiles can also be considered as part of the hybridisation of manufacturing with new products being developed that incorporate sensors that enable monitoring to be undertaking. There are also niche products being produced by British firms that blend technical textiles with medical technologies, for example textiles that contain chemicals that are released through contact with the skin. Technical textiles are also part of the aerospace sector as they are part of the emerging composite industry that is beginning to play a critical role in the development of new aircraft. These linkages between related industries are important and reveal that new innovations can emerge at the interface between different manufacturing and service sectors.

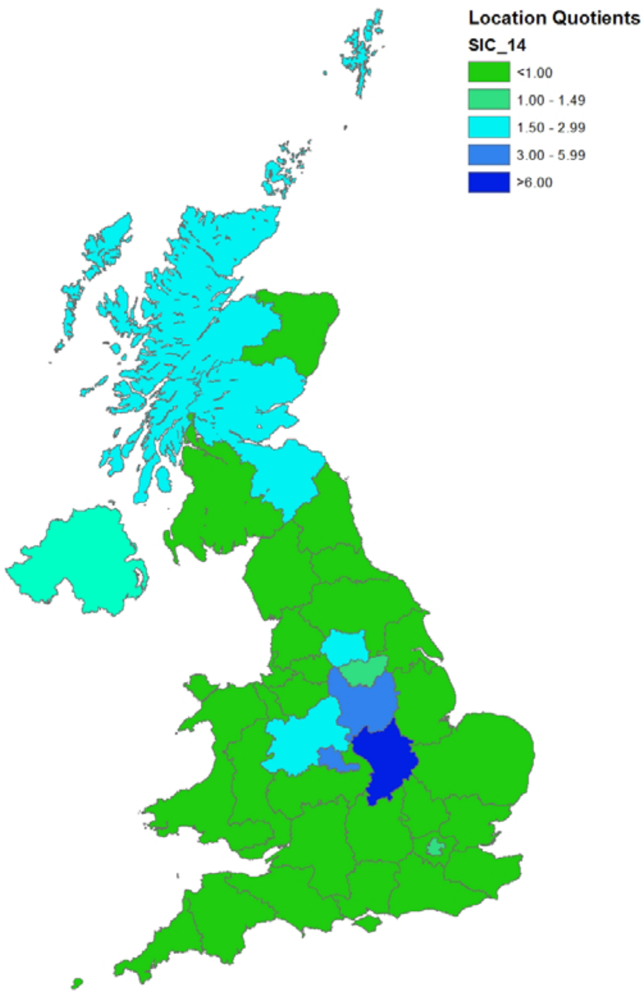


Figure 14. Localisation of wearing apparel industry (SIC 14) at the regional scale (NUTS2)

6.10 The future evolution of the space economy

This analysis of key sectors of British manufacturing has highlighted the complexity of the functioning economic geography that has developed. Extreme concentrations of manufacturing activities do exist, but manufacturing activities are also distributed or footloose. The geography of UK manufacturing is partly a reflection of the impact of historic influences on the location of industry.

This analysis has not identified interrelationships between different manufacturing and support activities, but it is important to consider these relationships. The aerospace industry has a very distinct geography compared to the other transport industries. It is much more localised and its geography is strongly related to specific support industries (R&D, SIC 72.1) and the manufacture of testing and navigation equipment (SIC 26.51).

The automotive (SIC 29), shipbuilding (SIC 30.1) and other transport (SIC 30) sectors have a geography that has links to technical testing (SIC 71.2) and fabricated metals (SIC 25). Supporting services that are critical to the competitiveness of manufacturing firms often have a different geography to manufacturing firms. These non-production aspects of manufacturing include technical testing and the provision of specialised design and professional business services. These services are generally located in southern England, but there is some overlap between these services and in particular between the location of the aerospace industry and R&D and between technical testing and more traditional manufacturing activities. The support services, however, have a more ‘footloose’ geography compared to manufacturing.

The future evolution of the UK’s manufacturing space economy will be closely related to existing assets. These assets include firms, people, the research and innovation ecosystem, raw materials and business and professional services. The UK needs to maintain and enhance the core supply chains that are critical for the country’s major manufacturing activities. The UK will lose major manufacturing activities or fail to attract major manufacturing foreign direct investment if the country’s manufacturing supply base continues to erode. This erosion is only partly related to competition from producers located in low-cost economies. Major challenges exist within the UK related to energy prices and to skill shortages or hard-to-fill vacancies and it is these issues that will play a significant role in any further reductions in manufacturing capacity and capability. The future geography of British manufacturing will reflect the current geography, but sustained growth will only occur through the development of supportive national and local policies. These policies include educational, research and innovation, regulations, national standards, land-use planning, infrastructure and trade agreements.

This account of the geography of British manufacturing has identified concentrations of manufacturing activities. It has highlighted the continued importance of the United Kingdom’s geography of manufacturing that began to emerge during the nineteenth century (Chisholm, 1925). For many years it has often been assumed that the decline of British manufacturing was related to structural problems found in the country’s manufacturing heartlands. Such problems included poor management, unionisation, labour costs, skills deficiencies, under-capitalisation and an absence of innovation (Comfort, 2012). The traditional centres of British manufacturing experienced waves of deindustrialisation as firms failed and factories relocated production to cheaper locations. Surviving firms, however, restructured in the face of globalisation by altering their business strategies. The UK has many extremely successful manufacturing firms and also firms that would benefit from process and product innovations. The manufacturing heartlands need to be conceptualised as locations that contain capabilities and innovative firms that have the potential to contribute towards the rebalancing of the British economy. It is to these places that we now turn our attention.

7. Reconceptualising manufacturing: implications for the future

Traditionally, older manufacturing regions have often been considered to be locked into old forms of mass production based on outmoded technologies while new forms of innovative production develop in new regions. This represents path dependency in which previous decisions and investments determine current investments and economic outcomes (Martin and Sunley, 2006). This view has been challenged by research that shows that firms have the potential to evolve and to break out from path dependency to create new development pathways. This form of economic evolution was identified by Schumpeter when he described capitalism as a ‘perennial gale of creative destruction’ in which economic structures are transformed from within and in which old structures are destroyed and replaced by new ones (Schumpeter, 1942: 83). Research on the Midwest region of the United States has shown how the area’s industrial base shifted from mass production to a new model of production based on continuous improvement and the integration of suppliers into the product development process (Florida, 1996). This new path has been driven, on the one hand, by increased FDI in manufacturing that has transferred new practices, processes and technologies and, on the other hand, by foreign competition that encouraged Midwest firms to develop new ways of organising production and to spread new approaches to production down their supply chains. In this context, larger firms operated as hub firms that identified new forms of production and accelerated the diffusion of new ideas through their supplier network (Gray and Golob, 1996; Christopherson and Clark, 2007: 1223).

In the UK, the acquisition of the Rover Group from British Aerospace in 1994 by BMW led to the introduction by BMW of a supply chain improvement initiative or ‘process improvement through variability reduction project’. In 1996 Rover set a maximum target of 1000 defective parts per million (ppm) entering the company from suppliers and the supply chain initiative was intended to reduce this to 300ppm in 1997, 100ppm in 1998, 50ppm in 1999 and 25ppm by the year 2000. Rover provided assistance in the form of Rover’s Supplier Development Engineers who visited suppliers to assist in the identification and removal of variation in the production process and suppliers had to convert an internal member of staff into an in-house consultant. BMW’s sale of Rover in 2000 and MG Rover’s eventual collapse in April 2005 did not negate the impact of BMW’s supply chain interventions that had a beneficial impact in ensuring the survival of the West Midlands automotive supply chain (Rover Task Force, 2000). In this context, BMW had introduced MG Rover’s supply chain to new routines.

It is important to consider whether some regions can avoid becoming locked into old forms of production. Thus, is it possible for a region to remain on a growth trajectory? This is a difficult issue as a region consists of a complex set of sub-economies that are supported by physical infrastructure as well as softer infrastructure, for example, schools, universities and health care. A regional economy consists of many different types and sizes of firms. Some firms will fail and close and some will fail to grow. The key question is what differentiates growing firms from failing firms. Regional economies with high concentrations of growing firms and more resilient firms will be more successful economies. Such firms can be in any sector. The question may be related to the environment in which the firms are located or may be determined by processes that lie within the control of the firm. Long-term firm survival in the face of severe competition is an important but under-researched process and plays an important part in the resilience of a regional economy. One of the few UK studies of this process explored the survival strategies of two extant West Midlands based engineering firms that were established in the mid eighteenth century and mid nineteenth century. This analysis identified that what is distinctive about these firms is that throughout their history they have maintained the capability and flexibility of producing both standardised and customised products and services, by adopting hybrid production systems, investing in technologies and skills in-house, maintaining engineering capabilities and by contracting out metal processes that are no longer viable for them to continue in-house. Over time and since the late twentieth century, the dependency on a single location and local production and supply networks had also diminished. These firms were open to external ideas and focussed on the development of innovative products (Begley *et al*., 2009). These were learning firms. To maintain a vibrant regional economy it is important to have a group of firms that are well-managed and who appreciate the importance of both process and product innovation.

The provision of infrastructure is important as the ability to move raw materials and finished goods easily and cheaply is a key locational aspect of the geography of manufacturing. The link between the research and innovation ecosystem in a locality is another infrastructural element, but this is complex. The best companies identify the best research organisations to work with irrespective of location; smaller firms either draw upon their own responses or use local providers. The presence of a skilled workforce is critical (Bryson *et al*., 2008). The education of skilled workers requires skills that are developed in universities and further education establishments. Economic growth within UK manufacturing requires an approach that will carefully align educational provision with the needs of major industrial sectors. This is a complex task that requires careful coordination of national and local policies. This implies that one policy implication is ensuring that key local industries, especially industries that are geographically concentrated, have a direct relationship with the educational system. Ideally there should be a supportive research and innovation ecosystem with developed relationships between research institutions, universities and private sector businesses.

Since 2008, the United States has experienced a revival in manufacturing with the first sustained increase in manufacturing employment since 1997 (Christopherson, 2011). This recent revival takes place in the context of thirty years of decline in manufacturing employment as the American economy experienced a process of rebalancing that included growth in financial and business and professional services. Like the United Kingdom there has been an upsurge in political interest in the revival of manufacturing in the US (Best, 2001; Lipscomb, 2011). The requirement for a strong American manufacturing sector is not a new idea (Clark, 2012; Clark and Clavel, 2012). In 1987 Cohen and Zysman argued that America needed to retain a strong manufacturing base. In a recent analysis of US manufacturing Christopherson argued that:

> "… when we look at where the potential for expansion of US manufacturing is greatest, we are looking at the remnants of supply chains and specialised knowledge in regional labor markets that constituted the original strongholds of US manufacturing. If we are intent on building US manufacturing jobs fast, we need to focus on those regional strengths and how to rebuild them. This will not be easy. Just as manufacturing was written off in the US economy, so were these centres of killed labour and specialised knowledge" (Christopherson, 2011: 6).

This analysis of US manufacturing would also apply to the UK. Christopherson's analysis of American manufacturing has much in common with Florida's (1996) earlier analysis. In another analysis she notes that in the US advanced new technologies have emerged in unlikely places and that these include the old industrial cities in the American Rust Belt. She notes that many ‘Rust Belt cities have the assets needed to support process and product innovation, as well as the commercial application of new technologies’ (Christopherson, 2009). Her argument rests on the existence of ‘phoenix industries’ rather than industrial clusters. To Christopherson phoenix industries have ‘”initial advantages”: they benefit from pre-existing personal networks, technical skills, and market knowledge that have developed over a long time, the products of investments in R&D and the workforce made during the heyday of American manufacturing’ (Christopherson, 2009). This argument is based on the strategic assets that old industrial regions still possess including specialised engineering departments and research programmes. These networking and asset advantages will reflect the activities of existing firms and sectors that have the potential to be transformed into phoenix industries. In the UK the recent transformation of Jaguar Land Rover into a highly profitable concern reflects the reworking of existing assets and the rise of a ‘phoenix firm’. Perhaps the key question is that some regions and firms avoid being locked into a trajectory that eventually leads to decline. This is an important research question whose answer revolves around the activities of knowledge-based organisations within the region, for examples, universities, but also firms that have long term investment strategies that are focussed on developing new products and services and modifying existing products and processes.

The presence of specialised university research capabilities explains some of the continued location of major private sector R&D activities in America’s old industrial heartland. In the US, much of the federal science and technology investment is funnelled through research centres housed in both private and public universities. These centres embed an innovative institutional infrastructure in the region. For older industrial regions, capacity is often directly related to regional manufacturing. For example, the optics and photonics research at the University of Rochester and the Rochester Institute of Technology in New York or the aerospace-related research at the University of Akron in Ohio.

However, there are two important variables connecting this research and development capacity to sustaining regional manufacturing. First, phoenix industries are very different to old manufacturing industries as they consist of many small and medium-sized firms and rarely make complete products, but specialise in the production of high-value sophisticated components that are sold to equipment manufacturers. As a consequence, regions with strong research universities but without dynamic small firm networks frequently find those innovations commercialised elsewhere. Essentially the regional economy lacks the ability to absorb product and process innovations (Feldman and Desrochers, 2003; Mayer, 2011). Second, for newer regional economies, without established manufacturing capacity, the investment in university-based high-tech research can have very little immediate impact on localised manufacturing. Again, it is not just a question of capacities to innovate but of capacities to uptake that innovation (O’Mara, 2005). And this is a question of specialised regional labour markets and small firm networks. In 2011-2012, the Obama Administration’s *Advanced Manufacturing Partnership* (AMP) studied how the manufacturing revival could be sustained and expanded. The Partnership argued for a rethinking of how research centres transfer technology highlighting the need to “push innovation down the supply chain.” In other words, in a vertically disintegrated world of small firm networks, it is not enough to transfer technology to a large end user if the goal is to maintain a dynamic, localised network of small manufacturers (Clark, 2012, 2013).
These are two different policy objectives. Policies that support the development or

activities of large firms should also contribute to the activities of SMEs. The issue concerns the development of diverse local economies that include a group of interrelated or interacting SMEs and larger firms. SMEs provide opportunities for additional employment growth whilst a region that is too dependent on a single large firm is potentially exposed to too much risk. The large firm may begin to disinvest and to allocate investment to other countries.

The realisation that phoenix industries are playing an important role in the renaissance of American manufacturing has important policy implications. It highlights the importance of building on a region's existing strengths and also a country's sectoral strengths. It also emphasises the importance of investing in university research centres that would make an active contribution to developing the next generation of competitive manufacturing firms.

8. On-shoring and new geographies of manufacturing

The rise of the first global shift or the relocation of manufacturing from developed market economies to other locations was conventionally driven by differentials in factor inputs with the most important differential being labour costs. The US Bureau of Labour Statistics 2012 analysis of manufacturing labour costs identified that the nine countries with the highest manufacturing hourly compensation costs were all in Europe, but that the UK was only 17th in the ranking and had lower labour costs compared to the US and Germany. Average hourly labour costs in manufacturing have been increasing in China and India at a faster rate than those in the United States, but were still less than four per cent of the US level (Department of Labour and Bureau of Labour Statistics, 2012: 30).

Labour is only one factor input and is most critical in manufacturing processes that are labour intensive rather than capital intensive. Manufacturers located in low labour cost locations tend to substitute labour for capital investment whist companies located in high labour cost locations control labour costs by investment in equipment and in process innovations that enhance productivity. This accounts for the jobless growth that has been experienced by manufacturing sectors in countries like the UK and US. The offshoring of manufacturing jobs to low labour cost locations reflects one driver behind the development the first global shift. Nevertheless, the ability of manufacturing firms located in high labour cost locations to substitute labour with machines and to concentrate on high-value or advanced manufacturing is transforming the global geography of manufacturing. Cost control combined with the development of new forms of competitiveness based on advanced manufacturing (Bryson and Rusten, 2011) is leading to a new geography of global manufacturing. Part of the new geography includes the return of some manufacturing activities from low cost locations to developed market economies.

There has been considerable emphasis placed on the importance of supporting infrastructure for the competitiveness of economic activities in regional economies (Christopherson and Clark, 2009). Much of this literature has its origins in accounts of Silicon Valley, California, and Route 128, Massachusetts (Kenney, 2000). There is evidence to suggest that local higher and further educational providers can play a key role in stimulating innovation in regional economies through the provision of high-quality programmes that support local industry and via academics that are involved in the activities of local firms (Saxenian, 1996: 67). The comparative analysis of Silicon Valley with Route 128 revealed that higher education providers in Silicon Valley were more engaged with local firms than community and state colleges in Massachusetts. This meant that large and small firms located along Route 128 had difficulties in recruiting skilled employees and many of the region's larger firms began to develop internal training programmes. This disadvantaged smaller firms that could not afford to develop internal training programmes. Regions that have developed strategic linkages between firms and local educational providers appear to be the most innovative and competitive (Saxenian, 1996; Christopherson and Clark, 2009). Appropriate skills training will be provided locally and important research relationships will develop between academics and businesses that have the potential to create new commercially viable products.

Research on British manufacturing has identified the importance of the co-location of design and research and development services with manufacturing. Design consultancy firms are key sources of external business service knowledge, expertise and innovation in post-industrial economies. Industrial design plays a critical role in the competitiveness of manufacturing firms (Bryson and Rusten, 2011). Business services (BS) expertise is developed locally, regionally and nationally to support the needs of local clients. This means that BS expertise is geographically differentiated as it is formed around local client need. Particular regions will develop local concentrations of BS firms that have formed around the requirements of local clients. In a series of papers, MacPherson and Vanchan explore the economic geographies of industrial design firms in the United States (Vanchan and MacPherson, 2007, 2008; MacPherson and Vanchan, 2010a & b). In America there is 'a noticeable geography of design service specialisation across the nation. Specifically, the types of services offered in any given metropolitan centre tend to mirror the structure of local production (i.e. prominent or dominant sectors)' (MacPherson and Vanchan, 2010: 84). The geography of industrial design:

> "… tends to mirror the geography of production (which includes both high-and low-technology industries). For example, over 60 per cent of the design consultancies in the Los Angeles area are focussed on electronics or aerospace markets, 76 per cent of Detroit's design companies serve the automotive or machinery sectors, and half of San Francisco's design companies cater to clients in the aerospace industries" (MacPherson and Vanchan, 2010: 84-5).

Many products are designed in the USA and Europe and manufactured elsewhere. It might be argued that developed market economies will be the best location for highly paid, graduate jobs involved in the design and development of products, but that manufacturing (fabrication and assembly) should be undertaken in low cost locations. In 2007 the Confederation of British Industry (CBI) undertook an analysis of modern manufacturing in the United Kingdom based on a stand-alone survey of over 1500 companies (CBI, 2007). This was supplemented by data obtained from a Business Trends survey undertaken in June 2007 by the *Engineering Employers Federation* (EEF) (CBI, 2007). Companies were asked the following question: What importance do you attach to co-locating each pair of activities? The activities were 'subtasks' in production projects that produced physical products. The subtasks involved research, design and development, production and assembly, logistics and integration, brands and marketing, sales and service provision (Table 5). Over half the firms considered that it was very important to co-locate R&D with Design and Development, and 64 per cent of firms stated that it was important or very important to co-locate production together with design and development. This is an extremely interesting finding as it suggests that the offshoring or global sourcing of production might eventually go hand-in-hand with the offshoring of related design and development subtasks. The analysis also highlighted the importance of establishing sales and service provision close to the point of consumption and that these subtasks can be dislocated from tasks concerned with design, development and production.

This has important policy implications for the UK. It means that considerable effort should go into maintaining and developing design and R&D clusters in the UK, but the emphasis should also be on ensuring the co-location of manufacturing. Policies should be developed to encourage companies that have offshored manufacturing from the UK but still retain design capability in the UK to consider returning production to the UK.

Table 5 The importance Placed by Companies on the Co-location of Functions

Percentage of firms saying it is (very) important to co-locate each pair of functions							
	Research	Design & Development	Production & Assembly	Logistics & Integration	Brand & Marketing	Sales	Service Provision
Research		63	36	10	23	23	14
Design & Development	63		64	22	31	38	28
Production & Assembly	36	64		68	18	27	36
Logistics & Integration	10	22	68		10	28	34
Brand & Marketing	23	31	18	10		67	35
Sales	23	38	27	28	67		56
Service Provision	14	28	36	34	35	56	

Note: Table compiled from data collected from a survey of 267 manufacturing companies located in the UK. The survey was conducted from the 10th to the 24th October 2007.

Source: After CBI, 2007

Over the last four years a new trend has emerged in the geography of manufacturing production. This is the repatriation of production work back to developed market economies (Lipscomb, 2011). This process is often described as ‘onshoring’ or ‘reshoring’ (Bryson, 2007). Wage inflation, escalating shipping costs, the increased cost of land, the strengthening of China’s currency have all contributed to eroding China’s cost advantages in manufacturing. Countries like the UK and the US are becoming lower cost locations for some manufacturing activities (Lipscomb, 2011). The concentration of manufacturing in China’s coastal cities has contributed to cost inflation. The decision by some firms to shift production to China’s interior produces additional problems related to poor transportation and shortages of skilled labour. In 2009 a survey of 300 manufacturing firms located in the UK identified that 14% of firms had brought production back to the UK from abroad over the past two years (EEF/BDO, 2009).

On-shoring is also occurring in the USA with a small but growing number of firms repatriating production including General Electric, NCR and Caterpillar (Lipscomb, 2011). There are three processes at work here. First, there is the repartition of production from low-cost locations. Second, is investment in on-shore production capability that enhances capacity and, third, companies that were sourcing components from overseas are switching to local producers. Detailed research on this process has yet to be undertaken, but the evidence so far suggests that there are seven drivers behind the on-shoring of manufacturing production (EEF/BDO, 2009; Mulhall and Bryson, 2013; Lane, 2012):

i) Initially the decision to send production to low-cost locations was based on the advantages of cheap labour rather than total costs (labour, transportation, management, multiple business trips). Labour inflation has been occurring in low-cost economies combined with increases in fuel costs that have led to escalations in shipping costs. Firms are shifting production on-shore as cost savings were not as great as anticipated and many of the labour cost saving are now being eroded by escalating shipping costs. Labour increasingly accounts for a small proportion of a product’s manufacturing costs. This means that, for many products, wage inflation combined with escalating shipping costs will reduce the savings gained from outsourcing to China. For many goods, a full cost analysis increasingly reveals that limited cost savings can be obtained from manufacturing in China compared to the UK. A full cost analysis includes transportation, plants and facilities, communication, supply chain risks, warehousing and labour.

ii) The production of products outside the home market can lead to long product-delivery cycles. This means that companies are much less responsive to customer demands. Speed and closeness to market are becoming significant drivers of firm success (Bryson *et, al,* 2008). The implication is that offshore manufacturing will be undertaken closer to market or that firms will have production capability in a lower-cost location combined with production capability closer to market. This is particularly important for firms that produce products that are customised to meet the needs of consumers or are sold on the basis of short-term fashion cycles. Thus, clothing companies like Zara or River Island that produce products to meet the needs of rapid alterations in fashion must balance the benefits of sourcing products from low labour cost locations with the requirement to design and source products extremely rapidly (Tokatli, 2008). In many cases, this means that manufacturing must occur close to market and combine production facilities based in low and high labour cost locations.

iii) There have been concerns with the quality of products supplied by producers located in low-cost locations (Midler, 2011).

iv) Concerns related to the theft of intellectual property (Bryson and Rusten, 2011) including product and process innovations. Product innovations can be copied from afar by reverse engineering, but it is much harder for overseas competitors to copy process improvements that include tacit knowledge.

v) The economic downturn that commenced in 2008 has reduced the order size for some components (Mulhall and Bryson, 2013). This makes it impossible for firms to order from low-cost producers located in China and elsewhere. Another driver is the reluctance of firms to tie up valuable capital in large overseas shipments. Firms have thus begun to seek alternative local suppliers willing to supply small batches.

vi) Companies are beginning to appreciate the benefits of co-locating design and development with production managers and assembly workers. This enables a close dialogue to occur between design and development and manufacturing. This dialogue can ensure that problems are identified and attended to rapidly Alterations at the prototype stage that come from this dialogue can identify redundant parts and reduce unit costs. The location of design and manufacturing close to market also ensures that discussions can occur between producers and consumers that have the potential to identify incremental improvements to existing products or even completely new products. That is, end-user innovation in product and process innovations are identified via interactions between producers and consumers (von Hippel, 2005)

vii) During the Twentieth Century labour differentials played an important role in the evolving global geography of manufacturing. Energy differentials will play a much more important role during the current century and may displace labour costs as the key driver behind the evolving global geography of manufacturing (Mulhall and Bryson, 2013). This is especially the case for energy intensive manufacturing activities. The on-shoring of manufacturing to the US is partly a response to the collapse in energy prices. This collapse has been driven by the US Governments concern with energy security and the investments that have been made in alternative energy sources including hydraulic fracturing. A recent report noted that the American chemicals industries: "... surge this decade in investment, jobs, and incomes has been largely spurred by low natural gas prices, a result of the rapid incorporation of new drilling techniques to extract shale and other unconventional gas supplies in the US. Investment in the US is now competitive with overseas locations. And the new gas fields have spurred investment not only in the Gulf of Mexico region, but across the US. For instance, a petrochemical processing, 'Cracker,' plant is to be constructed in the Pittsburgh metro owing to its proximity to shale gas supplies" (IHS , 2012:4).

On-shoring is occurring in most sectors including transportation goods, computers and electronics, fabricated metal products, machinery, plastics and rubber, appliances and electrical equipment, furniture, ceramics and textile (BCG, 2011) and in the majority of developed market economies. Low volume products in which labour accounts for a minor proportion of total costs are most suitable for on-shoring and such products include automotive and aerospace parts, appliances and construction equipment. In the US companies like Master Lock, Ford, Honda, General Electric, Caterpillar and Intel have onshored manufacturing jobs. In November 2012 Hornby, the model maker, decided to return the production of its model paint brand, Humbrol, from China to the UK. This decision was prompted by escalating labour costs in China combined with the transportation costs. Another example is Laxtons Ltd, Guiseley, and West Yorkshire. This is a spinning company that was established in 1907 and is now a design-driven yarn manufacturer. Like nearly all British textile companies production was offshored, but it has now returned to Yorkshire. The company invested in state of the art spinning technology. Returning manufacturing to Yorkshire substantially reduced the firm's carbon footprint, reduced lead times and increased the firm's control over quality and raw materials. The new specialist fancy yarn machines are used by very few firms in the world and they enable Laxtons to combine different spinning technologies and to target new markets.

It must be appreciated that onshoring may be a relatively minor process and, in the American context, has been argued to be 'a trickle' rather than a 'flood' (Davidson, 2010). It should be noted, however, that before the recession there was a significant lack of interest in the future of US manufacturing. Indeed, there was a wide consensus that outsourcing was inevitable and the policy response was to "compensate the losers" of globalisation rather than counter the underlying process. As a consequence, there was little analytical attention paid to the exceptions to the rule.

The seven reasons for onshoring explored above, are the drivers behind the return of manufacturing to developed market economies and the reasons why - for many successful manufacturers - it never strayed abroad. Firms often strategically retain some degree of manufacturing near their design headquarters. For example, Nike produces some shoes in Portland, Oregon, US, to protect its intellectual property from counterfeiters. Bicycle manufacturers, including Trek in Wisconsin, retain production in the region. Small firms in photonics and medical devices often produce in the US to maintain quality control (Clark, 2013). The policy challenge is to identify why some firms stay and whether those reasons can be amplified through policy to compel other firms to onshore as well.

Many labour-intensive products will continue to be manufactured in low-labour cost locations. Developments in machine tools may reduce the labour content required to produce some labour-intensive products opening the possibility of the return of more manufacturing to high labour cost locations. Some high-value products that are inexpensive to ship, for example mobile phones, laptops and tablet computers may continue to be produced abroad. But on-going innovations in manufacturing processes and technologies will always provide an opportunity to return manufacturing to developed market economies. The recent development in the on-shoring of manufacturing highlights that it is possible to compete on quality, delivery speed, customisation and even price with producers located in lower-cost locations.

9. Manufacturing: the next industrial revolution

The on-shoring of manufacturing to developed market economies may be transformed from a trickle into a flood with major innovations in manufacturing technologies. It is possible to argue that we are at the start of a new industrial revolution - a third industrial revolution - that has the potential to transform the geography of global manufacturing. The United Kingdom must ensure that it is at the forefront of these technological developments. This will involve investment in research and development in this area, encouraging firms to adopt the new technologies, educating the wider population by ensuring that these developments are explored in secondary schools and implementing strategies that will create skilled labour. These technological developments are combined with escalations in labour rates in core low labour cost manufacturing locations. In 2012 the TSB undertook an analysis of the future of high-value manufacturing in the UK (TSB, 2012a). This identified five cross-cutting strategic themes that underpin the current and future global competitiveness of high-value manufacturing in the UK (TSB, 2012a: 4). These themes are:

1. Resource efficiency that involves ensuring that UK manufacturing firms are protected against scarcity of energy and other resources.
2. Developments in manufacturing systems that will increase the global competitiveness of UK manufacturing technologies through the application of efficient and effective manufacturing systems.
3. The creation of innovative products through materials integration that involves integrating new materials, coatings and electronics into new products.
4. The development and application of new agile and more cost-effective manufacturing processes.
5. The development of new business models that will enhance profitability and competitiveness.

Many of these strategic themes include innovations that have already been explored in this report, for example, the hybridisation of manufacturing represents a new business model that also involves the development of new innovative products. There are many different drivers behind alterations in manufacturing production systems that will occur over the next decade. These include evolutions of existing technologies including new applications based on sophisticated embedded electronics and also products in which new functionalities are possible through upgrading embedded software. Many of the developments that will occur reflect an interplay that is occurring between the use of new materials and the blending of different technologies to create new products. A good example of the latter process is the creation of intelligent textiles that combines traditional textile techniques with new materials and technologies. The emergence of intelligent textiles is an excellent example of a phoenix industry.

Manufacturing is at the start of another industrial revolution. This revolution has two drivers. First, the last two decades has seen the emergence of China and the Asia Pacific as an important location for the manufacture of both low and high-value added products. The global geography of manufacturing has shifted away from many high labour cost locations as companies focussed on cost control. Since the late nineteenth century manufacturing firms have searched for locations that provide them with location-specific advantages often related to cost (Vernon, 1966; Dunning, 2001). The competitiveness of nations revolves around the existence of related suppliers, factor conditions including labour and raw materials, the presence of sophisticated consumers and competition (Porter, 1990). The rise of Asia Pacific as an important manufacturing location has been related to advantages in factor conditions, but many of these advantages are being challenged by wage inflation and the emergence of a large internal consumer market. Alterations within Asia Pacific countries combined with energy volatility have the potential to transform the geography of global manufacturing. Second, developments in technology and this includes new materials, the application of electronics to create new solutions, miniaturisation and the design and development of sustainable products including lightweight products. These developments also include new energy and resource efficient manufacturing processes. A key development is the emergence of new techniques for fabricating products that have the potential to revolutionise production processes and these are considered in this section. These two on-going developments have important implications for the future of manufacturing in the United Kingdom: 1) alterations with Asia Pacific countries and 2) new technologies. It could be argued that these factors will contribute towards the development of a new industrial revolution. These developments will be examined in turn.

9.1 Demographics in China

China's adoption in the 1970s of a one child policy was instrumental in reducing the country's historic high birth rates. Four decades on, the consequences of this policy are now beginning to exert profound demographic effects nationally (Chen, 2009). A rapidly ageing population, greater incidence of chronic diseases and disability, improved longevity, and higher standards of living among an emerging middle class are increasingly regarded as threats to the future well-being of Chinese society. The country already has about 108 million elderly (people aged 65 and over), or over one-fifth of the world's elderly population, and this number is expected to triple by 2050. In other words, China will become an 'old' society before its economic development is ready to underwrite the fundamental economic and political challenges posed by such demographic transition. China's demographic time bomb is ticking and should explode in 10–15 years time (Linge 1998; Zhang and Goza, 2006; Chen, 2009; Daniels, et. al., 2011). The demographic problem is also combined with inflation. Production costs are rising and manufacturing is already beginning to relocate from China. Combined with the development of China's internal consumer market, this suggests that the flow of manufactured goods from China will slow down and production will have to take place elsewhere.

The production of high volume manufactured goods with high labour costs will continue to be based in lower labour cost locations. For the European market, the production of high volume, but low-value products will be located in Eastern Europe and Turkey. But Eastern European manufacturing firms are beginning to shift from competition based on lower labour costs to other forms of competition and this shift is driven by wage inflation. China and the Asia Pacific will continue to be important providers of such products but especially in sectors that they have developed specialised expertise and capabilities. Manufacturers located in China are currently searching for lower cost locations in other Asian low-labour cost economies. The continual shift of production capability to lower cost locations will be an on-going feature of all economies, but this is complicated by rising transportation costs and new ways of producing products that remove some of the cost advantages related to low cost labour economies. Potentially there will be a manufacturing renaissance in countries like the UK but focussed on the design and production of high-value added products (Bryson *et al*. 2008; Bryson & Taylor 2010).

9.2 Emerging technologies

The history of much manufacturing is based around subtractive methods in which material is removed by cutting, drilling and other forms of machining. Subtractive manufacturing has been supplemented by technological developments that have given rise to additive manufacturing techniques, rapid prototyping or 3D printing (Wohlers, 2001; Yan, and Gu, 1996; Kumar and Kruth, 2010; TSB, 2012b). Developments in additive manufacturing have the potential to revolutionise manufacturing.

Additive manufacturing is a process in which a three dimensional solid object is produced by laying down successive layers of material (liquid, powder, or sheet materials) controlled by a digital file. The digital file can be produced by 3D computer-aided design (CAD) model data, CT and MRI scan data, and data created from 3D digitising systems. The development of 3D printing means that it now possible for components and products to be developed using Computer Aided Design (CAD) and printed using a 3D printer. In the UK there are many opportunities for the adoption of additive manufacturing in key sectors such as aerospace, medical devices and implants, power generation, automotive, the production of replacement parts and the creative industries.

Innovations in additive manufacturing have the potential to shift manufacturing production away from capital intensive mass production based in large plants to a network of distributed manufacturing facilities that would focus on the production of mass customised products. Additive manufacturing comes with a number of benefits and these include:

- A decrease in lead times from design to products that are ready for market.
- A resource efficient approach with no wastage.
- The ability to customise products.
- No requirement for specialist tooling. This reduces the scale of capital investment required to manufacture products.
- New developments in additive manufacturing are associated with rapid production throughputs.
- Limited defective parts.
- Parts and products can be designed to optimise functionality rather than for effective subtractive manufacturing.
- The ability to develop a hybrid manufacturing process that combines the benefits associated with subtractive and additive manufacturing.
- The ability to produce parts with the same functionality as parts produced by subtractive manufacturing, but with fewer raw materials. These products are much lighter.
- New products that can only be made by additive manufacturing. The layer process enables the manufacture of very complex shapes and there are few geometric limitations compared to subtractive manufacturing.

There are a number of research challenges that need to be overcome. These include scaling up the additive manufacturing process and overcoming some difficulties with the surface finish of products produced by additive manufacturing.

The cost of 3D printers is declining and very small firms are now able to afford to purchase small 3D printers. Developments in 3D printing or additive manufacturing have the potential to transform manufacturing and to produce a new geography. In theory, additive manufacturing could eliminate the subcomponent section of the supply chain. Thus, the emphasis would shift from cost-competition for the subcomponents to pre-production elements including 1) product design, 2) process design (software), and 3) materials (esp. quality and purity). Indeed, this would produce a very different production geography.

These developments will be related to the expiry of key patents, the formulation of less expensive materials and the creation of machines that print at fast speeds. 3D printing makes it possible to produce light weight structures that are extremely strong and optimise the relationship between material content and performance. All this will lead to the development of entirely new businesses and business models. It is possible to argue that additive manufacturing is the most important technological development in manufacturing since the introduction of CAD. Developments in additive printing means that individuals and small firms will have the capability to develop, design and print new products. 3D printers are being developed for domestic use and it would become possible for an individual to purchase a product file that enables them to print a product at home.

Contract providers of 3D printing services already exist and increasingly individuals and firms will be able to purchase customised products that are printed locally. Individuals will be able to download a 3D file to a company which will then print the object. A good example of this type of ‘service’ is provided by Shapeways, New York, which provide 3D printing services on demand. This technological development makes it extremely simple to customise products and to alter the relationship between manufacturing and consumers. Technically minded individuals will be able to develop products that might be tested by companies that specialise in selling products that can be printed at home or by a provider of 3D printing services. This means that warehouse inventory levels will be significantly reduced as more products can be printed close to the point of consumption. There are important sustainability and climate change implications as 3D printing makes it possible to localise and customise the production of many manufactured product. This would lead to the development of a much more distributed geography of production, but with centres for design and development. In effect, places that retain integrated design and production capacities will benefit, especially those with experience of absorbing process innovations.

It is critical that the United Kingdom is at the forefront of the development and application of 3D printing to manufacturing. The UK has a well-established and equipped additive manufacturing research community with 81 organisations involved in research since 2007, including 24 universities and 57 companies (TSB, 2012b: 17). There are a number of constraints on the United Kingdom’s ability to benefit from additive manufacturing. First, the research focus is based in universities and research laboratories and this suggests that currently the technology is ‘more laboratory-focused than shop floor focused’ (TSB, 2012b: 17). A policy initiative is required to raise awareness of this technology amongst manufacturing firms. Second, secondary schools must become core sites for introducing people to this new technology. Additive manufacturing must become part of the syllabus in a number of subjects including art, design and technology and business and management. Third, additive manufacturing is based on a new value chain that produces the technically complex powders that are required to print parts. The UK has yet to develop capability and capacity in the production of the powders required for

3D printing. This will be a major constraint on the development of additive manufacturing in the UK. Fourth, the UK has one commercial company involved in the production of additive manufacturing production technology (Renishaw plc) while Germany has six and the US ten (TSB, 2012b: 11). This means that the UK is not yet at the forefront of innovations in the development and production of 3D machine tools. At the moment the UK additive manufacturing industry is fragmented and dispersed. Its geography reflects uncoordinated investments. There is an important opportunity for the UK to ensure that additive manufacturing begins to function as an integrated and co-ordinated sector. This would enhance knowledge exchange and contribute to stimulating innovation.

Additive manufacturing will transform manufacturing. It may contribute to the on-shoring of production as customised parts can be printed close to the point of consumption. There are dangers in that the rise of 3D printing may have implications for the production of machine tools in the UK. The UK needs to develop capacity and capability in additive tooling to prevent the substitution of locally produced machine tooling with additive tooling manufactured overseas. Nevertheless, additive tooling will not supplement more traditional machine tools, but will support such tooling through the development of hybrid manufacturing that blends subtractive with additive techniques.

10. Conclusion

The new industrial revolution in the geography of global manufacturing is in its very early stages. It will vary dramatically from industry to industry, depending on technology, transportation costs, labour content, the competitive strengths of countries with low labour costs and the strategies of individual firms.

The drivers of this new geography of manufacturing are complex and include alterations in factor inputs, transformations in manufacturing technologies and the blending of services with manufacturing to create new hybrid production systems and hybrid products. The on-shoring or return of manufacturing to the UK from lower cost locations is partly driven by increasing transportation costs, but also a concern with quality and producing closer to the market. Balancing cost control with non-cost elements of product – heritage, design, location, speed of delivery, customisation – is becoming an important element of manufacturing competitiveness. For many British manufacturing companies labour costs have become a relatively minor cost. Increasingly energy costs are becoming a more important influence on the geography of manufacturing. Energy costs take two forms. First, is the energy required to produce a product and, second, the energy involved in transportation. Escalating energy costs have important implications for manufacturing policy in the UK as energy costs and availability could drive manufacturing offshore (Mulhall and Bryson, 2013).

The blurring of the division between manufacturing and services and the rise of hybrid production systems and hybrid services represents an important opportunity for British manufacturing. The emergence of hybrid products suggests that the UK no longer requires an industrial policy, but a production policy. An industrial policy represents a policy solution for the last century rather than the current century. A critical driver behind the new manufacturing revolution is technological developments. New production processes and technologies will transform manufacturing. Developments in additive manufacturing are both an opportunity and threat to British manufacturing. An opportunity as manufacturing firms based in the UK will be able to produce customised products that would impossible to create with conventional machine tooling. A threat as the UK is yet to develop significant capability in the production of 3D printers and in supply of powder.

A key focus in this report has been to explore the local geography of manufacturing. Regional industrial specialisations are not disconnected from the national economy but rather are engines that drive distinct nodes in an organisationally complex and geographically distributed supply chain. Agglomeration economies - geographically embedded technology/industry specialisations generating scale economies - do not exist independently from national and global production systems. Instead, these regional economies constitute an integrated system of specialised design and production sites in a distributed network of interlocking supplier and customer firm relationships. This is an important point; clusters or localisations of manufacturing activity should not be considered as separate from the wider production system of which they are apart. Increasingly policymakers are recognising that the geographic distribution and organisation of innovation and manufacturing matters - and, it matters a lot.

This analysis highlights the current state of manufacturing in the UK. The results point to a real potential for sustained growth in established sectors where design and innovation play a key role in production processes not just end products. Industrial geographers have tracked the spatial implications of shifts in the organisation of production processes in response to process innovations for some time and made similar points (Stone, 1973; Mudambi and Helper, 1998; Glasmeier, 2000; Rutherford and Holmes, 2007 & 2008; Christopherson and Clark, 2009; Treado and Giarratani, 2008; Helper *et al*, 2011; Bryson and Rusten, 2011; Helper and Krueger, 2012). Nevertheless, the policy implications of this research have not been developed. In May 2012 a Brookings Institution report entitled 'Locating Manufacturing', assembled a body of empirical research on the geographic distribution of manufacturing in the US and made the argument for policies that take the spatial organisation of manufacturing into consideration. The argument was that manufacturing policies must be designed and implemented that are based on an understanding of the spatial organisation of production (Helper and Krueger, 2012). This is a key point. Although consideration of the nuances of industrial geography is not unheard of in policy circles, it is generally applied to leveraging political interests instead of designing policies and programs. This distracts from the more empirical economic realities surrounding how and why the spatial organisation of economic activities is arranged and rearranged in "the new economy".

Recent debates in the US about the viability and sustainability of the American automotive industry illustrates these points. In the US, automotive manufacturing is associated with a single city: Detroit. The automotive industry is also associated with a single set of end products: cars and trucks. In fact, the automotive industry is far broader in terms of its geographic distribution and product diversity. The "automotive industry", and particularly its supplier networks, is interwoven across a range of civilian and military manufacturing applications. In fact, the automotive industry is far more geographically distributed and diverse in scope than the popular discourse would indicate. Further, policies that support the automotive industry tend to support manufacturing across the economy because the industry is woven into the national industrial ecosystem. In other words, the criticism that targeting the automotive industry is government "picking winners and losers" does not match the empirical reality.

In a 2011 analysis of the supply chain in the US automotive industry, Susan Helper and colleagues studied the supplier network supporting the automotive industry. Unlike many other studies, this one analysed the dynamics of the supply chain down to third tier suppliers. The authors describe the policy challenge as a result of shifts in production processes as follows:

> "Before 1980, the Detroit Three automakers (Ford, GM, and Chrysler) - who at the time accounted for 90% of the nation's auto sales - produced and designed many of their own parts in-house. Since that time, they have shifted much of this work to supply chains of financially independent firms that now design and produce about 70% of the industry's parts. The major automakers share these supply chains, creating a "free-rider" situation in which automakers lack the incentives to invest adequately in their supply bases. That is, if an automaker helps its supplier develop a new technology, the supplier's other customers—typically the first automaker's rivals—will enjoy the same improvements without having contributed. As a result, automakers and large suppliers don't have an incentive to make such investments. Rather, they shift costs down the supply chain to weaker suppliers. These practices improve the larger firms' financial performance in the short run, but in the longer run rob the entire supply chain of incentives to invest. Automakers in other countries such as Japan and Germany have avoided this collective problem by developing institutions that govern supply chains" (Helper *et al*., 2011).

The point here is that firms in the supply chain bear the brunt of the shifts of risks and costs that come with vertical disintegration. As a consequence, the assumption that supplier firms have the resources and capacities to manage technology and labour market upgrading just as the end producer firms did in a vertically integrated era is inaccurate. Further, this false expectation leaves places specialised in supply chain production functions with less investment than before. Thus, to reinvigorate a resilient manufacturing sector, a renewed focus on small and medium sized enterprises (SMEs) is necessary. This is not because small firms are the job generators for the new economy - although they might be. It is because SMEs are critical to a functional supply chain capable of absorbing innovations.

Manufacturing policy should be concerned with pushing technology down the supply chain, not simply transferring innovations to high-tech start-ups. This requires modifying existing R&D institutions to provide technical assistance to SMEs on innovative production processes as well as designing and prototyping innovative products. These innovative processes include energy efficiency, life-cycle product design, and the adoption of better, greener, safer materials. Research and development (R&D) facilities should focus on international standards and certifications (environmental, labour, corporate codes of conduct, systems and logistics) that provide suppliers with increased credibility with end producers in a global supply chain. In addition, access to shared facilities and the technical assistance they provide should be free to SMEs, particularly small firms co-located with the R&D institution.

Research centres should become integrated into a workforce investment system, allowing for the broad training of workers on specialised equipment and with specialised production systems. This training would be delivered in partnership with technical schools. Although university-based R&D facilities have long served as training grounds for graduate and undergraduate students enrolled in research universities, these facilities can and should be a resource available to a broader set of incumbent workers. An effective manufacturing policy would consider these career ladders. Further, investment in a skilled and educated labour market almost never triggers trade concerns about subsidises internationally or inter-jurisdictional competition domestically. This is particularly true if that training is technology-specific rather than industry or firm specific. In other words, training is one way to support small firms by offsetting labour costs.

Manufacturing policy provides an opportunity to reframe the engagement of research universities in national and regional innovation systems (Dyson, 2010). Research universities are broadly distributed, have established research and educational capacities, and house many of the existing R&D institutions and innovation programs. However, under current conditions, universities often act as revenue-seekers rather than neutral research and educational intermediaries in a national/regional innovation system. Universities are forced to compete for funds rather than collaborate on implementation. They are also forced to internally prioritise revenue-generating activities over an educational, service, and outreach mission. For universities to serve the critical role of implementation intermediary in a renewed manufacturing policy, they simply must have adequate resources targeted at enhancing the contributions they make towards enhancing innovation within manufacturing firms.

References

Aldrich, H. (2004), *Organizations Evolving*, Sage: London

Aldrich, Howard E., Geoffrey M. Hodgson, David L. Hull, Thorbjørn Knudsen, Joel Mokyr and Viktor J. Vanberg (2008), ‘In Defence of Generalized Darwinism’, *Journal of Evolutionary Economics*, 18(5), October, pp. 577–96.

Allen, J.C. (1961), *British Industries and their organization*, Longmans: London

Anderson, J. C. and Narus, J.A. (1995), ‘Capturing the Value of Supplementary Services’, *Harvard Business Review*, January-February: 75-83

ABS (2010) *Annual Business Survey: Revised Results 2010*, Office for National Statistics.

Appold, S.J. (1995), ‘Agglomeration, Interorganizational Networks, and Competitive Performance in the U.S. Metalworking Sector’, *Economic Geography*: 71: 1: 27-54

Asheim, B.T. and Isaksen, A. (2002), ‘Regional innovation systems: The integration of local ‘sticky’ and global ‘ubiquitous’ knowledge’, *Journal of Technology Transfer*, 27: 1: 77

BCG, (2011), *Made in America, Again: Why manufacturing will return to the US*, Boston Consulting Group: Chicago

Begley, S., Taylor, M.J., and Bryson, J.R. (2009) Firms as Connected Temporary Coalitions: Organisational Forms and the Exploitation of Intellectual Capital, *The Electronic Journal of Knowledge Management,* Vol. 7 (1): 11-20.

Best, M.H. (2001), *The New Competitive Advantage: The Renewal of American Industry*, Oxford University Press: Oxford

Blackaby, F. (*ed*.) (1978), *De-industrialisation* , Heinemann: London

Bluestone, B. and Harrison, B. (1982), *The Deindustrialisation of America*, Basic Books: New York

Boschma R. A. and Wenting R. (2004), The Spatial Evolution of the British Automotive Industry, *Papers in Evolutionary Economic Geography*, O5.04, Utrecht University.

BRES (2010a) *Business Register and Employment Survey: Great Britain 2008-10, September*, Office for National Statistics, Nomis.

BRES (2010b) *Business Register and Employment Survey: Northern Ireland 2008-10, September*, Office for National Statistics, Nomis.

Bryson, J.R. (2007) ‘A ‘Second’ Global Shift? The Offshoring or Global Sourcing of Corporate Services and the Rise of Distanciated Emotional Labour’, *Geografiska Annaler 89B (S1): 31-43*

Bryson, J.R. (2009), *Hybrid Manufacturing Systems and Hybrid Products: Services, Production and Industrialisation,* University of Aachen: Aachen.

Bryson, J.R. (2010), ‘Service Innovation and Manufacturing Innovation: Bundling and Blending Services and Products in Hybrid Production Systems to Produce Hybrid Products’, in Gallouj F. (Ed), *Handbook on Innovation in Services*, Edward Elgar: Cheltenham: 679-700

Bryson , J.R.and Daniels, P.W. (2007) ‘Small and medium-sized enterprises and the consumption of traded (producer service expertise) versus untraded knowledge and expertise’ in Bryson, J.R. and Daniels, P.W. (eds.) *The Handbook of Service Industries in the Global Economy*, Edward Elgar: Cheltenham: 295-310

Bryson, J.R. and Rusten, G. (2011), *Design Economies and the Changing World Economy: Innovation, Production and Competitiveness*, Routledge: London

Bryson, J.R .and Taylor, M. (2010), ‘Competitiveness by Design and Inimitability through Service: Understanding the dynamics of firm-based competition in the West Midlands Jewellery and Lock Industries’, *The Service Industries Journal*, April 2010 volume 30 number 4: 583 – 596

Bryson, J.R., Taylor, M. and Cooper, R. (2008), ‘Competing by Design, Specialization and Customization: Manufacturing Locks in the West Midlands (UK)’, *Geografiska Annaler: Series B, Human Geography* 90 (2): 173-186 .

Bryson, J.R., Daniels, P.W. and Warf, B. (2004), *Service Worlds: People, Organisations, Technologies*, Routledge: London

Cagliano, R. Acur, N. and Boer, H. (2005), ‘Patterns of change in manufacturing strategy configurations’, International Journal of Operations and Production Management, 25: 7: 701-718

CBI, (2007), *Understanding Modern Manufacturing Sur*vey, Confederation of British Industry: London, unpublished report and PowerPoint presentation.

Chen, S. (2009). Aging with Chinese characteristics: A public policy perspective. *Ageing International*, *34*(1), 172–188.

Chisholm, G.G. (1925), *Handbook of Commercial Geography*, Longmans, Green and Co: London.

Christopherson, S. and Clark J., (2007), ‘Power in Firm Networks: What it Means for Regional Innovation Systems’, *Regional Studies* 41: 9: 1223.

Christopherson, S. and Clark, J. (2009), *Remaking Regional Economies: Power, labor and firm strategies in the knowledge economy*, Routledge: Abingdon

Christopherson, S. (2009), ‘Manufacturing: Up from the Ashes’, *Democracy: A Journal of Ideas*, Issue 14: Fall 2009

Christopherson, S. (2011), ;Riding the Small Wave in Manufacturing to More Good Jobs and a More Diverse Economy’, Paper presented to the ‘ Big Ideas for Job Creation in a Jobless Recovery’ Conference, The Institute for Labor and Employment, University of California, Berkeley, June 16-17, 2011

Clark, J. (2012), ‘Is There a Progressive Approach to Innovation Policy?’, *Progressive Planning* (Winter 2012): 17-21.

Clark, J. (f 2013), *Working Regions: Reconnection Innovation and Production in the Knowledge Economy*, Routledge: New York

Clark, J. and Clavel P. (2012), ‘Introduction: Progressive Approaches to Manufacturing Policy’, *Progressive Planning* 190 (Winter 2012).

Cohen, S. and Zysman, J. (1987) *Manufacturing Matters: The Myth of the Post-Industrial Economy,* London: Basic Books.

Comfort, N. (2012), *Surrender: How British Industry Gave Up the Ghost 1952-2012*, Biteback Publishing: London.

Cooke P. and Piccaluga, A. (2004) (Eds.), *Regional economies as knowledge laboratories*, Edward Elgar: Cheltenham

Daniels, P.W. and Bryson, J.R. (2002) 'Manufacturing Services and Servicing Manufacturing: changing forms of production in advanced capitalist economies', *Urban Studies*, 39, 5-6: 977- 991.

Daniels, P.W. , Rubalcaba, L., Stare, M., Bryson J.R., (2011), 'How Many Europes? Varieties of Capitalism, Divergence and Convergence and the Transformation of the European Services Landscape', *Tidschrift voor Economische en Sociale Geografie,* 102: 2: 146-161

Davidson, P. (2010), 'Some manufacturing head back to the USA', *USA Today*, August 6th.

Dunning. J., (2001), 'The eclectic (OLI) paradigm of international production: past, present and future', *International Journal of Economics and Business*, Vol 8, No 2, pp 173-190

Dyson, J. (2010), *Ingenious Britain: Making the UK the leading high tech exporter in Europe: A report by James Dyson*, available at: http://www.russellgroup.ac.uk/uploads/Dyson-report-Ingenious_Britain1.pdf

EEF/BDO (2009), *Manufacturing Advantage: How manufacturers are focussing strategically in an uncertain world*, EEF/BDO: London

Feldman, M. and Desrochers P. (2003), 'Research universities and local economic development: Lessons from the history of the Johns Hopkins University', *Industry and Innovation* 10(1): 5.

Fingleton, E. (1999), *In Praise of Hard Industries: Why manufacturing, not the new economy, is the key to future prosperity*, Orion: London

Florida, R. (1996), 'Regional Creative Destruction: Production, Organization, Globalization, and the Economic Transformation of the Midwest', *Economic Geography*: 72: 3: 314-334

Florida, R. (2005), *The Flight of the Creative Class*, HarperBusiness: New York

Friedman, T.L. (2005), *The World is Flat: A Brief History of the Globalized World in the Twenty-first Century*, Allen Lane: London

Gershuny, J. and Miles, I.D. (1983), *The New Service Economy*, Frances Pinter: London

Glasmeier, A. (2000), *Manufacturing Time: Global Competition in the Watch Industry, 1795-2000*, The Guilford Press: New York

Gosney, M. (Ed.) (2011), *Rebuilding UK Manufacturing: What must happen next to ensure the long term success of UK Industry*, Findlay Media: Kent

Gray, M. and Golob, E. (1996), 'Big Firms, Long Arms, Wide Shoulders: The 'Hub-and-Spoke' Industrial District in the Seattle Region', *Regional Studies* 30:7: 651.

Helper, S., and Krueger T., (2012), *Locating American Manufacturing: Trends in the Geography of Production*, , The Brookings Institution: Washington DC

Helper, S. with Park, K.W., Krueger, T., Warofka, A., Zhu J., Eisenmenger, W. and Peshek B., (2011), *The US Auto Supply Chain at a Crossroads: Implications of an Industry in Transformation. Driving Change: Greening the Automotive Workforce*, Case Western Reserve University: Cleveland

Hudson, R. (2001), *Producing Places*, The Guildford Press: New York

Klepper, S. (2002), ‘The capabilities of new firms and the evolution of the US automobile industry’, *Industrial and Corporate Change*, 11: 4: 645-666

Klosterman, R. E. (1990),

IHS (2012), *US Metro Economies: Outlook - Gross Metropolitan Product, and*

Critical Role of Transportation Infrastructure, Report prepared by IHS for:

The United States Conference of Mayors and the Council on Metro Economies and the New American City, IHS Global Insight

Isard, W. and Azis, I. (1998), *Methods of Interregional and Regional Analysis.* UK, Ashgate: Aldershot *Community Analysis and Planning Techniques*, Rowman & Littlefield: Savage, Md.

Kenney, M. (2000), *Understanding Silicon Valley: The Anatomy of an Entrepreneurial Region*, Stanford University Press: California

Kumar, S. and Kruth, J.P. (2010), ‘Composites by rapid prototyping technology’, *Materials and Design*, 31: 850-856

Lane, D. (2012), ‘On-shoring Boosts Manufacturing rebound’, *Manufacturing Engineering*, 148: 2: 96

Lash, S. and Urry, J. (1993), *Economies of Signs and Spaces*, Sage: London

Lever, W.F., (1991), ‘Deindustrialisation and the Reality of the Post-Industrial City’, *Urban Studies,* 28: 6: 983-999.

Linge, G. (1998), ‘An Overview: Towards Sustainable Development?’, *in*: G. Linge, (ed.) *China’s New Spatial Economy: Heading towards 2020*, Oxford University Press: Oxford.

Lipscomb, T. (2011), *Re-Made in the USA: How we can restore jobs, retool manufacturing and compete with the World*, John Wiley: New Jersey

Liversy, F. (2006) *Defining High Value Manufacturing*, Cambridge: Institute for Manufacturing: Cambridge.

MacPherson, A., Vanchan, V. (2010a) The outsourcing of industrial design by large US manufacturing companies: an exploratory study. *International Regional Science Review*, *33: 3-30.*

MacPherson, A.D. and Vanchan, V. (2010b), ‘Locational Patterns and Competitive Characteristics of Industrial Design Firms in the United States’, in Rusten, G. and Bryson, J.R. (Eds), *Industrial Design, Competition and globalization*, Palgrave MacMillan: Houndsmill: 81-92.

Malmberg, A. and Maskell, P. (2002), ‘The elusive concept of localization economies: towards a knowledge-based theory of spatial clustering’, *Environment and Planning* A: 34: 3: 429-449

Martin, R, and Sunley, P. (2006), ‘Path dependency and regional economic evolution’, *Journal of Economic Geography* 6: 395-437

Maskell, P. and A. Malmberg (1999), ‘Localised learning and industrial competitiveness’, *Cambridge Journal of Economics*, 23 (2): 167-186.

Massey, D. (1984) Spatial Division of Labour: Social Structures and the Geography of Production, London: MacMillan

Mayer, H. (2011), *Entrepreneurship and Innovation in Second Tier Regions*. Edward Elgar: Northampton, MA.

Midler, P. (2011*), Poorly Made in China: An Insider's Account of the China Production Game*, John Wiley & Sons: London

Mudambi, R. and Helper S. (1998), ‘The 'close but adversarial' model of supplier relations in the U.S. auto industry’, *Strategic Management Journal* 19:8: 775.

Mulhall R. and Bryson, John R. (2013), ‘The Energy Hot Potato and Governance of Value Chains: Power, Risk and Organizational Adjustment in Intermediate Manufacturing Firms’, *Economic Geography*, in press

Neely, A., (2007), ‘The Servitization of Manufacturing: An Analysis of Global Trends’, Proc. 14th European Operations Management Association Conference, Ankara.

Nelson R. and Winter, S. (1982), *An Evolutionary Theory of Economic Change*, Harvard University Press

O'Mara, M. P. (2005), *Cities of knowledge : Cold War science and the search for the next Silicon Valley*, Princeton University Press: Princeton, N.J

Ohmae, K. (1990), *The Borderless World: Power and Strategy in the Interlinked Economy*, Free Press: New York

Ohmae, K. (1995), *The end of the Nation State – the rise of regional economies*, HarperCollins: London

Peck, J. (2005), Struggling with the creative class. *International Journal of Urban and Regional Research* 29, 4, 740-770

Porter M.E. (1990), *The Competitive Advantage of Nations*. London: Macmillan

PricewaterhouseCoopers, (2009), *The Future of UK Manufacturing: Report of its Death are Greatly Exaggerated*, PricewaterhouseCoopers: London.

Rolls-Royce (2006), *MRMS® Mission Ready Management Solutions*, Rolls-Royce: London

Rolls-Royce (2007), *Annual Report 2007: A Global Business*, Rolls-Royce: London

Rover Task Force (2000) *Final Report and Recommendations to the Secretary of State for Trade and Industry*, RTF: Birmingham

Rusten, G. and Bryson, J.R. (2010), Placing and Spacing Services: Towards a Balanced Economic Geography of Firms, Clusters, Social Networks, Contracts and the Geographies of Enterprise, *Tidschrift voor Economische en Sociale Geografie*, 101:3: 248–261,

Rutherford, T. and Holmes J. (2008), ‘The flea on the tail of the dog': power in global production networks and the restructuring of Canadian automotive clusters’, *Journal of Economic Geography,* 8: 4: 519-544.

Rutherford, T. D. and Holmes J. (2007), ‘Entrepreneurship, knowledge and learning in cluster formation and evolution: the Windsor Ontario tool, die and mould cluster’*, International Journal of Entrepreneurship and Innovation Management* 7:2-5: 320.

Saxenian, A. (1996), *Regional Advantage: Culture and Competition in Silicon Valley and Route 128*, Harvard University Press, Cambridge, MA.

Schumpeter. J. (1942), *Capitalism, Socialism, and Democracy*, Harper and Row: New York

Simmel, G. ([1907] (*1990*), *The Philosophy of Money*, Routledge: London

Stone, K. (1973), ‘The Origins of Job Structures in the Steel Industry’, in Edwards, R.C. and Gordon D. (Eds), *Labor Market Segmentation*, Heath and Company: Toronto

Taylor, M.J. (2010), ‘Clusters: A Mesmerising Mentra’, *Tijdschrift voor Economische en Sociale Geografie*, Tijdschrift voor economische en sociale geografie**,** 101: 3: 276-286

Tokatli, N . (2008),’Global sourcing: insights from the global clothing industry – the case of Zara, a fast fashion retailer’, *Journal of Economic Geography*, 8: 1: 21-38.

TOPSI (2012) *Turnover and Orders in Production and Services Industries (TOPSI), April 2012*, Office for National Statistics.

Treado, C. D. and Giarratani F. (2008), ‘Intermediate Steel-Industry Suppliers in the Pittsburgh Region: A Cluster-Based Analysis of Regional Economic Resilience’, *Economic Development Quarterly* 22:1: 63.

TSB (2012a), *A landscape for the future of high value manufacturing in the UK A study conducted for the Technology Strategy*, Board Technology Strategy Board: London

TSB (2012b), *Shaping our National Competency in Additive Manufacturing,* A technology innovation needs analysis conducted by the Additive Manufacturing Special Interest Group for the Technology Strategy Board, Technology Strategy Board: London

U.S. Department of Labor and Bureau of Labor Statistics (2012), *Charting International Labor Comparisons* , U.S. Bureau of Labor Statistics, Washington, DC

Vanchan, V. and MacPherson, A. (2007), ‘The recent growth performance of US firms in the industrial design sector: an exploratory study’*, Industry and Innovation,* 15:1-17***.***

Vanchan, V. and MacPherson, A. (2008), ‘The competitive characteristics of U.S. firms in the industrial design sector: evidence from a national survey’, *Competition and Change*, 12: 262-280.

Vandermerwe, S. and Rada, J. (1988), ‘Servitization of Business: Adding Value by Adding Services’, *European Management Journal* 6, 315-324.

Vernon. R, (1966), ‘International Investment and International Trade in the Product Cycle, *The Quarterly Journal of Economics*, Vol 80, No 2, pp190-207

von Hippel, E. (2005), *Democratizing Innovation*, MIT Press, Cambridge M.A.

Wohlers, T. (2001), *Wohlers Report: Rapid Prototyping & Tooling State of the Industry Annual Worldwide Progress Report*, Wohlers Associates: Fort Collins, Colorado

Yan, X. and Gu, P. (1996), ‘A review of rapid prototyping technologies and systems’, *Computer-Aided Design*, 28: 4: 307-318

Zhang, Y., & Goza, F. W. (2006), ‘Who will care for the elderly in China? A review of the problems caused by China’s one-child policy and their potential solutions’, *Journal of Aging Studies*, *20*(2), 151–164.

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